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CHILD DEVELOPMENT

This number contains studies on physical development in youth; the development of perception and motor skill in children; the galvanic skin reflex in infants; and the child's responses in tests of color blindness.

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Comparative Youth

The Physical Aspect*

T. Wingate Todd

EPIPHYSIAL UNION

IT IS sufficiently obvious that the actual duration of infancy, childhood and youth varies enormously in different mammals. A rat reaches skeletal maturity in little more than two months, a dog in less than two years, a gorilla in approximately seven years[1] and a human being in about twenty. The relation of these periods to total life span cannot at present be estimated and indeed in all creatures except man the duration of life is a matter of accidental environment: it often terminates soon after or even before maturity is stabilized. Hinton, for example records his experience that in many thousands of modern and fossil arvicola (a field mouse) he has met with only two skeletons in which the epiphyses are united (7).

Elsewhere we have shown that current estimates of the age of union of epiphyses in man are inadequate in that they unjustifiably postulate an inherent great variability in time relationship which altogether obscures the age-order of union. While it is true that there is variability and that the scatter is greatest in the period between eleven and fifteen years of human life, the assumption of natural variability is unwarranted. Investigators have been misled by circumstances.

First the amount of skeletal material upon which the classic and traditional estimates are based is altogether too scanty for reliance. Observations have been copied from one account to another with slight alterations based upon evidence of no real worth. Most modern accounts can be traced to that of Henle in Gottingen in 1871 (6).

Secondly, radiographers, relying upon the essential accuracy of accounts in anatomical texts and lacking the actual material with which to compare their roentgenograms, have assumed reliability for their observations on date of union of massive epiphyses like those at the knee or hip. They have failed to realize that the medley of overlapping shadows renders impossible the reading of such roentgenograms without a thorough collateral training on actual anatomical material. They have not realized, as yet, that the occurrence of Hellman's stages (5) in preparation for union confuse the roentgenographic appearance for large diaphyso-epiphysial junctions. Their observations on these areas, numerous though they be, carry no weight at all in spite of impressive figures.

Thirdly, investigators have failed to

* From the Hamann Museum, Western Reserve University, Cleveland, Ohio.

recognize the peculiar complexities[2] of the human maturation schedule, being unaware of the manner in which this grows out of the primate pattern with extensive delays and scatter during puberty and the prepubertal period but presenting equally striking uniformity before and after these years. The evident erratic character of epiphysial union in hand and foot, occurring as it does in this period of irregularity, is no criterion of the time relationship of skeletal maturation elsewhere.

In this confusion it is imperative that the whole problem of skeletal maturation be investigated afresh and the human pattern elucidated by comparison with those of other mammals. Since we have only the scantiest information regarding the time relationships of the various features of skeletal maturation in mammals it is obvious that we start by investigating the maturation pattern without consideration of chronological age. Our themes then must be four, taken in series, and for the present our attention will be directed to actual epiphysial union.

1. The order of epiphysial union.
2. The time relationship of epiphysial union.
3. Experimental and other evidence of modifications in this time relationship.
4. Local expression of irregularities in skeletal maturation in epiphyses which ossify only in part like those of the human clavicle and symphysis pubis.

Some years ago Stevenson, under my direction, published an account of the age order of human epiphysial union in one of the most stable periods of human development, namely the early adult years between eighteen and twenty two (14). Our conclusions, there stated, have often been called in question but never proved inaccurate. Critics have produced no valid material to justify their objections. Some have relied upon their assumption that without control of observation upon actual skeletons they could identify union by roentgenographic methods, altogether oblivious of the fact that overlapping shadows present a misleading appearance of continuity in bone tissue (11, 12, 13). Other critics have utilized mammalian material in which the occurrence of pathological anomalies has been conceded (1, 2). The Hamann Museum of Western Reserve University, alone among institutions, houses a large enough collection of human skeletons from known individuals to make such an inquiry possible and we stand in no fear that our observations will ever be successfully refuted.

For the elucidation of this problem of age-characters in the skeleton we have at our disposal and have carefully studied eighteen hundred human skeletons of known persons including more than two hundred young people and adolescents, more than a thousand mammalian skeletons including one hundred and fifty anthropoids. All the human material and most of the mammalian skeletons are in the Hamann Museum. The majority of the remaining mammalian skeletons were examined, by the courtesy of Sir Arthur Keith, in the Museum of the Royal College of Surgeons, London. A comparatively few skeletons were found in

the American Museum of Natural History, New York, the National Museum, Washington and the Field Museum, Chicago. Observations on certain of the skeletons in these latter American collections were made by Stevenson but all the Reserve and College of Surgeons material and most of the small American series have been studied by myself.

THE DETERMINATION OF ORDER OF UNION.

It seems a very simple matter to arrange the epiphysial fusions in order but in practice difficulties arise through the imperfections which are found in skeletal material even under the most assiduous care. It may be, for example, that in skinning the animal the fingers and toes have been mutilated, or that in transport home from the field a part of one limb has been lost or possibly important bones like the clavicles. Then again some bones are missing in certain animals or so greatly modified that they lose their significance and themselves constitute a problem for investigation. Notable among these are clavicles, fibula, metacarpals, metatarsals, cervical vertebrae, pelvic girdle and hind limbs. Even if it is desired only to compare sequence of union within a single mammalian order some scheme must be devised to eliminate this difficulty. If the investigation be of larger scope the need is correspondingly more urgent.

The method used is, in essence, very simple. The several stages of fusion are evaluated. The evaluations for a particular epiphysis in all skeletons are summated and divided by the total number of skeletons in which that epiphysis is found. The record is kept in its fractional form and, for comparison, is reduced to a least common denominator for the group of material under investigation. In a certain group of rodents, for example, there were 51 skeletons. Of these, owing to defects, 50 had humeri, 49 had radii. Only 32 had acromion processes since these bone elements are often lacking in rodents. To compare the results of our observations on these epiphyses our fractional figures had to be reduced to a least common denominator of 51. The actual evaluations are no union 0; commencing union 1; recent union 3; complete union 4.

The precise amount of union displayed in any series of skeletons depends on the scatter of the several skeletons over the life span. So many diverse factors enter into the accidental determination of the series that it is unnecessary to make an enumeration. Some interpretation can be attempted in the chapters dealing with the several orders. Clumping, or, at the other extreme, wide dispersal of union in the several epiphysial sites may be merely an expression of the portion of the life span covered by the particular series of skeletons.

FEATURES OF EPIPHYSIAL UNION

Most epiphyses, as Parsons showed (10), form a more or less perfect cap so that, when embedded in deep soft tissue as at the hip, or when large and complicated as at the knee, the roentgenogram may yield but little information of the precise state of the diaphyso-epiphysial junction except to those observers who have carefully checked their roentgenograms on the

actual skeleton from which they were made. The only workers who have had adequate opportunity to do this are the little band of investigators in Western Reserve University.

Before actual union occurs there is a narrowing of the diaphyso-epiphysial gap, described by Hellman (5), with a slight condensation of bone tissue at the adjacent surfaces of diaphysis and epiphysis shown on roentgenograms as an indefinitely outlined whitish margin. When union commences it occurs erratically in the depths of the diaphyso-epiphysial plane and occurs last on the surface of the bone. The skeleton plainly shows first the close approximation of epiphysis to shaft with progressive narrowing of the gap and later an increasing fusion of the two bone elements. In the fresh bone there is a fine red line marking the site of union for about six months after the fusion is perfected. This stage we call recent union. The red line then becomes transformed into a white scar which in some places, lower end of radius and ulna for example, disappears usually in a few months but in others, such as the knee, may remain throughout life in modified form. When the white scar has developed we call the union complete. These features are just as plainly apparent in other mammals as in man and can be readily demonstrated by a little careful dissection.

COMPARATIVE ORDER OF UNION

Among existing orders of mammals there are 2 which are essentially primitive, providing opportunity for study of epiphysial union, namely the insectivores and the rodents. The former have adopted a safe mode of life which enables them to live long. They are comparatively rare in collections, are difficult to procure and, because of their relative immunity to capture, are often aged when obtained. The rodents on the contrary are easily obtainable and often gregarious. Then tend to die young, in groups,[3] so that they are numerous in museums and their skeletons usually show the unmistakable signs of adolescence or early maturity. Hence we shall utilize them as a starting point for our description.

It is not my intention at this time to present a detailed discussion of the order of union among the skeletal epiphyses. It will be sufficient to point out the general similarity of order pattern as an indication of the manner in which epiphysial union, as a manifestation of skeletal maturation, may be utilized to identify comparable points in the life-spans of very different animals. I have drawn up a table based upon the records of somewhat less than four hundred mammals from some of the earlier work, the later amplified tabulations being not yet completed. This table includes simply the epiphyses of the long limb bones excluding those of hand and foot. It covers all the primates and makes use of the rodents as an illustration of the relatively slight divergence to be found between vastly different mammalian orders.

The distal epiphysis of the humerus is the first to unite except in gorilla where the proximal epiphysis of the ulna unites slightly before it. The last epiphysis to fuse is the proximal end of the humerus though in orangs and gorillas the distal ends of radius and ulna lag somewhat behind it.

There is no great lapse of time between union of these three epiphyses in any of the higher primates. In man and chimpanzees radius and ulna precede humerus by a very short time and in gibbons all three unite together.

The medial epicondyle of the humerus closely follows the distal extremity in date of union. In anthropoids, except gorilla mentioned above, and in man the proximal end of the ulna unites in point of time between these epiphyses. There is however no great alteration in date of union of proximal ulna in these animals from the date in lower primates. In all it has attained a much earlier union than in rodents in which it fuses comparatively late. This epiphysis is the only one of those in the arm under consideration to show a marked change in order of union when primates and rodents are compared.

As for the epiphyses of the leg, those at upper end of femur always unite first in primates. In man and the large black anthropoids they are comparatively early in their fusion. Then follow distal tibia and fibula. Distal femur with proximal tibia and fibula unite last of the leg epiphyses and close together in time, the precise order varying slightly from one genus to another. In rodents the order is but little different. The same three epiphyses are the last to fuse but distal tibia and fibula climb to a position among the fusions at upper end of femur.

Were it possible to continue this survey without regard for space it would be possible to demonstrate a like similarity in epiphysial union over the entire skeleton. This demonstration must however await the complete publication of our researches. The claim has been illustrated that throughout the mammalia there is a definite and approximately uniform order of epiphysial union, modified indeed by influences quite imperfectly understood, but holding valid in the main. This uniformity is definite enough to enable us to identify the several phases in maturation of the mammalian skeleton and to compare with assurance identical phases in animals belonging to a single order. For the present purpose it suffices to restrict our attention to the anthropoids.

TOOTH ERUPTION AND SKELETAL MATURATION

From the examination of our immature anthropoid skeletons it is apparent that tooth eruption and epiphysial union progress together and that their inter-relationship is similar to that shown in human skeletons.

The subject of tooth eruption in anthropoids has been made a special study by Krogman (9) whose results are set forth in an article shortly to be published.

The dates of eruption of canines, premolars and second molars in man are subject to quite considerable variation but this, as we shall see, is a necessary corrollary of the specific human adolescent lag which we are later to discuss.

Tooth eruption, like skeletal maturation of which one feature is epiphysial union, can be violently disorganized by certain pathological states. In a series of thyroidectomized sheep for which we have to thank the late Professor Sutherland Simpson and

Doctor H. S. Liddell of Cornell University we have found repression of all skeletal maturation so that tooth eruption and epiphysial union alike are greatly delayed. Further than this one need not go at the moment. It is evident however that conditions of captivity may retard skeletal maturation. This, I believe, may be the explanation of Zuckerman's claim, from the study of five chimpanzees at the London Zoo, that dates of tooth eruption in the chimpanzee are practically the same as those for man (18).

Basing our conclusions in the first place upon such fragmentary observations as have been made upon the probable actual chronological age of anthropoids examined in captivity and upon the records of their tooth eruption, but amplifying these with our own quite extensive examinations of anthropoid skeletons we may state in general terms that an anthropoid of twelve months corresponds in development to a human being of two years, that an anthropoid of four years corresponds to a child of five, an anthropoid of six years to a child of twelve and an anthropoid of seven years to a youth of twenty.[4] For this last conclusion we are indebted to the comprehensive work of Doctor Yerkes on Congo, a mountain gorilla (15, 16). The skeleton of this animal, approximately seven years old, was sent to Doctor A. H. Schultz in Baltimore. Through the courtesy of Doctor Schultz both Doctor Krogman and I examined the skeleton and each independently assigned to it a maturation comparable between eighteen and nineteen years of human life, utilizing for this decision the epiphysial keys prepared by Stevenson on the Reserve human skeletons (14).

The opinion of Keith in 1899 (8) that the permanent teeth of the anthropoids are probably in place by the fourteenth year should perhaps be somewhat modified by the observations on Congo in which the permanent set was already complete except for the third molars and the canines.

Krogman working upon our anthropoid and Old World Ape material has stated the dates of eruption of teeth in terms of epiphysial union (9). On the basis of this comparison he notes that although tooth eruption in these primates does not slavishly follow the human pattern, yet, for practical purposes, at a given comparable epiphysial age the permanent teeth erupted are the same. "This does not bespeak identity in actual years but infers a practically uniform chronological sequence. It must be recognized that the entire growth process in anthropoids is accomplished in fewer years than in man, especially after the period of infancy."

THE ADOLESCENT LAG

The comparison of weight curves during the first year of life made by Dodge (3), shows a progressively diminishing scatter in both males and females. The Misses Hejinian and Hatt, working at the Merrill-Palmer School (4), have shown the stable and rather uniform character in progress of development in boys and girls between one and five years. Our own observations during the past four years on boys and girls from five to thirteen years, now in process of publication, demonstrates that there is a minor pro-

gressive acceleration of female skeletal maturation between six and eight years. During the period eight to nine years the females slow up so that the male maturation reaches that of the female at about the latter date. At ten years the girls again advance ahead of the boys and, shortly after the thirteenth birthday, are already at the stage reached in the boys about the fifteenth birthday. Thereafter they slow down once more and at about sixteen years and a half the maturation of the male skeleton has finally caught up that of the female. From this date onwards an increasing stabilization is significantly apparent and the years eighteen to twenty-two are remarkable for the uniform maturation of the skeleton in males and females which both keep to the same schedule. It is the stabilization at the approach of adult life between the eighteenth and twenty-second birthdays which we emphasized in Stevenson's article. Such adverse criticism as this demonstration has met is based upon lack of understanding of the manner of human maturation in relation to that of other primates and to a fallacious belief in the ease with which roentgenographic shadows of the larger diaphyso-epiphysial areas can be interpreted. We must again emphatically point out that those who assume their infallibility in interpretation by roentgenograms alone of Hellman's stages B. C. D. in the shoulder, hip, knee and even elbow, wrist and ankle, without careful training upon the actual adolescent skeletons themselves, from which the roentgenograms have been made, are taking upon their shoulders a heavy and, likely enough a crushing, burden.

Such peculiarities as are shown in the female accelerations between six and eight years and between ten and sixteen years, cannot occur without considerable scatter. It is therefore quite to be expected that we should find, as we do, a greater individual variability among girls than among boys. It is here intended simply to lay stress upon general trends and not to detail specifically the range or distribution of examples. Many girls show no greater progress than the boys and some are even retarded behind the boys. Questions relating to retardation and acceleration must be dealt with in another communication.

The scatter, both among boys and girls is greater in the period of ten to sixteen years than at earlier ages. In the light of our anthropoid studies this is intelligible. It is a reasonable corollary of the characteristically human and greatly extended developmental period of adolescence.

This adolescent lag in human skeletal maturation, with its corollary the adolescent scatter, is quite the most fascinating and instructive problem which we have opened up in our studies on growth. It is the key to better understanding of multitudinous complexities and difficulties of the second decade.

Adolescence is a figment of the mature imagination. The word itself is abhorrent to those to whom we apply it. The gorilla like all other mammals leaps from childhood to adulthood. The inception and maturation of its adult features cover but a period of months. A characteristic feature of man is his adolescent lag whereby the development of his adult characters occupies as many years as it does

months in the gorilla. This is the modern counterpart of the doctrine of human foetalization. When we note the divergence between different young people in the date and order of appearance of adult characters[5] we are merely observing in exaggerated perspective similar irregularities which are common to all mammals but are emphasized in mankind on account of his adolescent lag.

SUMMARY

1. A detailed and comprehensive analysis of mammalian epiphysial union, accompanying a quite exhaustive investigation of this problem in man, shows the essential unity in order and relationship of epiphysial union throughout the mammalia.

2. The occurrence of Hellman's stages B and C, namely the approximation of epiphysial bone to diaphysis, before union is begun, can easily be identified in hand and foot, but in the larger areas, shoulder, hip and knee, and even in elbow, wrist and ankle, obscures the precise state of the diaphyso-epiphysial plane and renders interpretation fallacious.

3. In order to check one's observations on the roentgenogram it is essential to examine anatomically the very bone roentgenographed. Lack of such training has led many honest workers into error. They have confirmed the existing fallacious textbook statements of date of union without realizing the inaccuracy of the method used.

4. Applying a simple valuation to the state of the diaphyso-epiphysial junction it is possible to express numerically the order of union and the relative period over which, for that particular group of skeletons whether human or mammalian, epiphysial union takes place.

5. The dates of epiphysial union and eruption of permanent teeth are related so that they may be regarded, for this purpose, as different aspects of the same phenomenon. Both order-pattern and date of union or eruption can be and are modified by pathological conditions of the body.

6. There is a chronological linkage for both epiphysial union and eruption of teeth which is normally stable for a particular animal but varies with the order or genus.

7. The special character of the primates is a lag of maturation throughout infancy and childhood. Nevertheless even in them adult characters quickly reach complete development once they have appeared.

8. The particular feature of man's development is his adolescent lag, and the scatter in individual variation which is most pronounced between eleven and fifteen years. The most stable and uniform periods of human skeletal development for both males and females are between one and five years and between eighteen and twenty-two years.

NOTES

Having had the privilege of submitting this manuscript to Professor R. M. Yerkes for criticism and comment I take the opportunity to add certain notes which will assist in

TABLE 1

Order of epiphysial union with number of examples in each series

MAN (151)	GORILLAS (27)	CHIMPANZEES (27)
Hum. dist.	Ulna prox.	Hum. dist.
Ulna prox.	Hum. dist.	Ulna prox.
Hum. med. ep.	L. troch.	L. troch.
L. troch.	Fem. head	Fem. head
Fem. head	G. troch.	G. troch.
G. troch.	Hum. med. ep.	Hum. med. ep.
Tib. dist.	Rad. head	Rad. head
Fib. dist.	Tib. dist.	Fib. dist.
Rad. head	Fib. dist.	Tib. dist.
Tib. prox.	Fem. dist.	Fem. dist.
Femur dist.	Tib. prox.	Tib. prox.
Fib. prox.	Fib. prox	Fib. prox.
Rad. dist.	Hum. prox.	Rad. dist.
Ulna dist.	Rad. dist.	Ulna dist.
Hum. prox.	Ulna dist.	Hum. prox.
ORANGS (22)	**GIBBONS (11)**	**OLD WORLD APES (77)**
Hum. dist.	Hum. dist.	Hum. dist.
Ulna prox.	Ulna prox.	Hum. med. ep.
Hum. med. ep.	Hum. med. ep.	Ulna prox.
Rad. head	Rad. head	Rad. head
L. troch.	L. troch.	L. troch.
G. troch.	G. troch.	G. troch.
Fem. head	Fem. head	Fem. head
Tib. dist.	Tib. dist.	Tib. dist.
Fib. dist.	Fib. dist.	Fib. dist.
Tib. prox.	Tib. prox.	Fib. prox.
Fib. prox.	Fib. prox.	Fem. dist.
Fem. dist.	Femur dist.	Tib. prox.
Hum. prox.	Rad. dist.	Rad. dist.
Rad. dist.	Ulna dist.	Ulna dist.
Ulna dist.	Hum. prox.	Hum. prox.
NEW WORLD MONKEYS (36)	**LEMURS (39)**	**RODENTS (136)**
Hum. dist.	Hum. dist.	Hum. dist.
Hum. med. ep.	Hum. med. ep.	Hum. med. ep.
Ulna prox.	Ulna prox.	Rad. head
Rad. head	L. troch.	L. Troch.
L. troch.	Fem. head	Tib. dist.
Fem. head	Rad. head	Fem. head
G. troch.	G. troch.	Fib. dist.
Fib. dist.	Fib. dist.	Ulna prox.
Tib. dist.	Tib. dist.	G. troch.
Fib. prox.	Fib. prox.	Fib. prox.
Tib. prox.	Tib. prox.	Rad. dist.
Rad. dist.	Fem. dist.	Ulna dist.
Ulna dist.	Rad. dist.	Fem. dist.
Fem. dist.	Ulna dist.	Tib. prox.
Hum. prox.	Hum. prox.	Hum. prox.

clarifying questions which arise from the conclusions given in the text and the manner of presentation.

(1) R. M. Y. These figures do not apply to growth (size) or sexual maturation. The gorilla assuredly is not fully grown short of twelve years or more. Congo was growing rapidly when I last observed her.

T. W. T. Maturity in weight, sex and skeleton are not synchronous. Our records on young adult women show increase in weight but not in dimensions after skeletal maturation. Full female stature is attained on the average just under sixteen years, skeletal maturity of long bones at twenty but weight continues to rise thereafter.

(2) R. M. Y. Are there not comparable complexities in the great apes. Though at present we have no measurements of psycho-biological development in relation to age in any anthropoid ape I should like to have the question of fact raised.

T. W. T. There undoubtedly are complexities similar in principle in anthropoids as in man. Observations on the growth and tooth eruption of our living South American monkeys indicate a pattern not dissimilar throughout primates but our distinctions are not yet fine enough. I intended to imply a pronounced difference between primates in general and anthropoids in particular on the one hand and non-primates of the other, by my comparison of dog and gorilla. I might have mentioned that skeletal maturity is reached in sheep before the third birthday. Uniformity of epiphysial picture throughout period of tooth eruption between appearance of second milk molar and second permanent molar indicates "concentration" of physical development (see also Bingham, H. C.: Growth and development of chimpanzees, Am. J. Phys. Anthropol., 1930, vol. 13, pp. 433–468). Confusion in eruption order of second permanent molar and premolars in anthropoids and Old World apes indicates the complexity to which you refer (see Krogman 9).

(3) R. M. Y. Do you mean when kept in colonial groups, or that they die in groups.

T. W. T. I referred to the finding of large numbers of skeletons commingled in one area. Paleontologists repeatedly comment on this. We have definite evidence of "mouse years" and migrations of hosts of such rodents which are cut off by death together. As such collections emphasize a uniformity of general epiphysial condition and this corresponds to the period of early maturity of the animal (averaging about seventeen to eighteen human years) I suspect such migrations to be a kind of "vernal urge."

(4) R. M. Y. Behavioral data would suggest less marked divergence, say six to ten and seven to fourteen years. So far there is no check observation on skeleton development aside from tooth eruption. I do not think Congo was comparable psycho-biologically with a woman of twenty, rather I should guess fifteen years.

T. W. T. I am dealing solely with physical aspects, namely skeletal differentiation and tooth eruption. In her skeleton Congo was between eighteen and nineteen human years; John Daniels I, in his skull, more than five human years and less than twelve. Dwina (See Bingham (2) above) was twelve and a half upon our records in human years. Bingham's chronological guess was four years eight months. I do not emphasize the exact number of years but merely the human lag. See also Krogman (9).

(5) R. M. Y. Would it not be safer to limit the statements to structural characters since our data on functions are so limited (especially in case of gorilla)? I suspect you are substantially correct but we certainly could not produce the supporting observations for behavior.

T. W. T. I did intend so to limit my statement but desire to project the reader's thought into the possibility of similar findings in other fields. We have little to guide us at present but tooth eruption and a plainly demonstrated expedition in epiphysial union, once it starts, after eruption of the second permanent molars.

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The Acquisition of Motor Skill in Young Children

A Study of the Effects of Practice in Throwing at a Moving Target[1]

J. Allan Hicks

THIS study is concerned with the effect of specific practice upon the ability of young children to hit a moving target by throwing a ball. Fundamentally the problem is to what extent young children improve in complex motor skills as a result of specific practice and to what extent as a result of other factors such as structural maturation and general practice which has a direct bearing on the specific skill.

The effect of specific practice was determined by giving 1 of 2 comparable groups of children practice in throwing at a moving target under controlled conditions while the other group was not given such practice. The added increase in skill of the practice group, as shown by tests, is attributed to specific practice because the other factors which might affect this increase can be assumed to be similar for the 2 groups.

[1] From the Washington Child Research Center. This study was completed while the author was a scholar in child development of the National Research Council at the Iowa Child Welfare Research Station. A detailed account of the study will be published as an Iowa study in child welfare.

A moving target test was devised and was the main test in this experiment. The Blackhurst arm strength test (2), the Wellman tracing path test (3), and the perforation test (1), were used as supplementary motor tests. This paper is a report of the results on the moving target test. The results on the supplementary tests in comparison with this test will be reported in a subsequent paper.

The subjects were 60 children ranging in age at the beginning of the experiment from two years, seven months to six years, five months. The distribution according to age and sex for the practice and control groups later described is given in table 1. The total group included 12 three-year-old children, 18 four-year-olds, 18 five-year-olds and 12 six-year-olds.

The 60 children were first given the initial moving target test and the three supplementary motor tests. They were then divided into two groups which were comparable in performance on the initial test on the moving target. The mean score of each group was 11.7 with a standard deviation of 5.7 for the practice group and 5.6 for the control group. As

shown in table 1, both groups were also comparable in age and sex distributions.

The 30 children in the practice group repeated the moving target test once a week for eight weeks. For convenience in carrying out this practice program an equal number of the children were tested on each of the school days, Monday to Friday inclusive. The one week interval was kept constant by testing the same children on the same day of the week throughout the experiment. A few deviations from this schedule were necessary because of absences but of the 240 practice records but 19 were off schedule more than three days.

TABLE 1

Age and sex distribution of children in practice and control groups for the moving target test

AGE	BOYS		GIRLS		TOTAL
	Group				
	Practice	Control	Practice	Control	
years					
3	2	2	4	4	12
4	4	4	5	5	18
5	3	3	6	6	18
6	4	4	2	2	12
Total	13	13	17	17	60

At the end of the eight weeks' practice all children were given the moving target test once each week for two weeks. This gave the practice group an initial test, eight practice tests and two final tests, a total of eleven. The control group was given the initial test and the two end tests, a total of three practices. Ten throws were given during a test period so that each child in the practice group threw 110 times at the target and each child in the control group 30 times.

Approximately three months after the initial tests the strength, perforation, and tracing path tests were given again to the 60 children. As nearly as possible the second series of tests was given in the same order as the first so that the intervals between first and last tests were approximately equal for all children on all tests. The average number of days elapsing between all first and last tests for the 4 motor tests was 83 days for the practice group and 82 days for the control group.

APPARATUS

The moving target test apparatus (fig. 1) was constructed for the learning experiment with young children. The target was moved along on horizontal tracks by means of an electric motor ($\frac{1}{4}$ horse-power direct current) so that the children had to adapt their aim and speed of throwing to this movement. The movements of the target were controlled by a speed reduction drive, pulleys, shafting, and a leather belt which was attached to the back of the target. This operating machinery was mounted upon a channel iron frame 10 feet long and 2 feet wide by means of suitable supports. The shafting and attached pulley on one end was mounted upon a platform which could be moved to adjust the drive belt. The entire apparatus except the target was painted black in order that the white and green target would stand out in relief. The target was started, stopped and reversed by means of a switch placed upon a table 8 feet in

front of the target and to the child's right when facing the apparatus. This location enabled the experimenter to observe to best advantage a child's movements in throwing without interfering with the test. Two rheostat speed controls were also placed upon this table enabling the experimenter to conveniently control the speed and movement of the target. On the basis of preliminary tests it was measured by a tape fastened along the upper guide track.

The target was large—4 feet in diameter—so that nearly all throws struck somewhere on its surface. In spite of this large size and the short distance of the children from the target—5 feet from the center of the running path—the younger children frequently missed entirely. This was usually due to their failure to throw

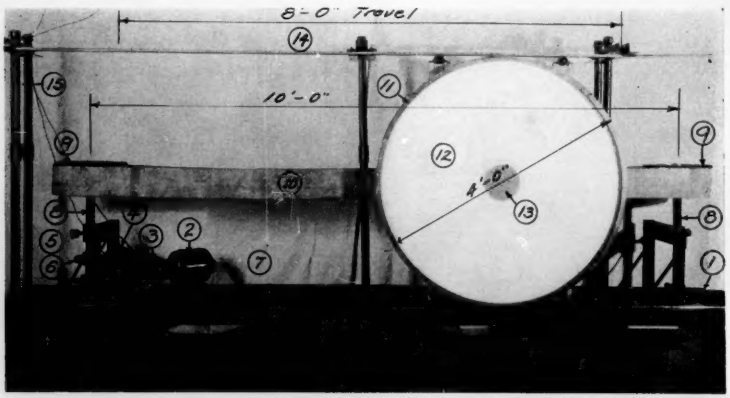

FIG. 1. MOVING TARGET APPARATUS

1, channel iron frame; *2*, one fourth h.p. direct current motor; *3*, coupling; *4*, speed reducer; *5*, worm wheel on speed reducer shaft; *6*, gear on pulley shaft; *7*, adjustable platform; *8*, pulley shafts; *9*, pulleys; *10*, leather belt; *11*, detachable outer ring; *12*, white oil cloth; *13*, green oil cloth; *14*, guide tracks; *15*, pipe frame brackets.

decided to maintain a constant speed of .33 feet a second throughout this experiment. The target slid on rollers that ran in channel iron guides for a distance of 8 feet. A child usually allows a target to move a short distance before throwing at it and the distance of 8 feet was sufficiently large to enable every child to decide to throw. The distance a child allowed the target to move before throwing was high enough. Even the older children occasionally threw wildly.

The target was constructed so that each time the ball struck it a permanent record was made, permitting a more accurate analysis of results than would have been possible otherwise. This was accomplished by placing the following parts of the target in the order named from back to front: heavy board back, copper screen wire

tacked to the board, carbon paper fastened over the screen covered board with the surface toward the front of the target, a record paper cut from newsprint, white oilcloth with smooth surface out, a bull's eye of green oilcloth 7 inches wide glued over the white oilcloth. The oilcloth was fastened to a removable ring bolted to the outer edge of the target by means of 4 wing nuts which could be quickly removed. The record paper was clipped to the oilcloth before putting the ring on the target and quickly replaced for each trial period after removing the ring. Six of these rings were made in order to facilitate record changing. When the ball hit the target a cluster of black dots was made on the record paper. These were clearly distinguishable even when the ball was thrown with little force.

A circle was cut from the center of the target board and attached screen and the detached part suspended in the opening by means of springs. When the ball hit the green oilcloth this suspended center was moved back and rang a bell attached to a frame on the back of the target. This arrangement not only gave the child the green bull's eye at which to throw but gave the added motivation of ringing a bell when the bull's eye was hit.

In order to make the test relatively comparable for all children a platform 6 feet square was used to adjust a child's height to the center of the target. These adjustments were made by means of blocks slipped under the corner of the platform so that the center of the target, 36.5 inches from the floor, would be one inch lower than the child's shoulder height. A few of the children were tall enough to stand on the floor when throwing. The children stood behind a foot board placed parallel with the target and with its center 5 feet from the center of the target's running path. Squash tennis balls 2.25 inches in diameter were used for throwing. A ball of this size was convenient for the children to grasp and easy to grip because of the rough surface.

For convenience in scoring the records a model of the circular target was drawn upon linen drawing cloth and mounted on an easel with a glass back. Concentric circles one inch apart and radial lines 4 degrees apart were drawn upon the model. When the record paper was mounted and a flood light behind the glass turned on, the distance of the center of impact of each throw from the center of the target and its angle were easily determined. This method saved the use of measuring instruments.

PROCEDURE

Every child was shown the apparatus before the tests were begun. After rapport seemed well established the child was brought in front of the target and the experimenter said, "See, this is a big target that runs on these tracks. (E pointed to target and tracks.) You stand here behind this board. (E pointed to the foot board and had the child take a position behind it approximately in the center and facing the target.) I'll start the target and show you how it runs. (The target was run across the eight foot path at the selected speed.)

Now I'll run it back again. (The target was reversed to its starting point.) I want you to throw this ball (the ball was held up so that the child could see it) at the target while it is moving and try to hit the pretty green part, here. (E touched green part.) When you hit the pretty green part a bell will ring like this." (E rang bell once with his finger.) The experimenter then held the ball out before the child at the child's shoulder height and directly in front of him and said, "Try to hit the pretty green part while it is moving and make the bell ring. Now I'll make the target move." (E started target.)

As the ball struck, the target was stopped and the number of the throws in the day's series marked on the spot on the oilcloth. A blunt steel stylus was used so that a mark was not left on the oilcloth but the number was reproduced on the record paper by pressure against the carbon. The experimenter also recorded the distance a child allowed the target to move before throwing by reading from the tape on the upper guide track as well as the hand used in throwing.

On successive throws on the initial test the instructions were, "Remember, try to hit the pretty green part while it is moving and make the bell ring. Now, I'll make the target move." For the first throw on all practice periods after the initial test the instructions were, "See, this is the big target that moves. Try to hit this pretty green part (E touched part indicated) here, while it is moving and make the bell ring like this. (E rang bell with finger.) Now, I'll make the target move." For throws after the first in practice periods the experimenter merely said, "Now, I'll make the target move."

Three preliminary throws and 10 practice throws were given on the initial test, but on all later periods but 10 throws were allowed. At all times the subjects were encouraged in their efforts. In no case, however, was a child given instructions in ways of improving his skill. At the end of each day's practice period the child was praised for his performance. The novelty of the moving target seemed to attract and maintain the interest of every child. Hitting the "green part" and making the bell ring was apparently a real goal. A few of the younger children who could not ring the bell seemed greatly pleased to hit the target or to come near the green part. In no case was any other motivation necessary.

The record blank when completely filled out contained the following information for each throw: the distance the target moved; the hand used in throwing; the manner of throwing; observational notes; the distance from the center that the ball struck; the score, obtained by substracting the number of inches the ball struck off center from 25, (for example, a throw striking five inches from the center of the target was given a score of 20 and a throw striking twenty inches from the center a score of 5); the angle of the spot the ball struck relative to a horizontal axis through the center of the target. The method of scoring follows the usual procedure of giving the better performances the larger scores. The angle values were later analyzed to show whether throws were high or low and to the right or to the left of the center.

TABLE 2

Average scores on moving target test, practice group

SEX	NUMBER	TEST I Av.	I S.D.	1 Av.	1 S.D.	2 Av.	2 S.D.	3 Av.	3 S.D.	4 Av.	4 S.D.	5 Av.	5 S.D.
3 year age group													
M.	2	6.4		8.8		5.2		4.9		7.8		10.4	
F.	4	3.2		4.6		5.4		4.6		4.8		7.8	
T.	6	4.3	3.8	6.0	3.6	5.3	2.6	4.7	2.0	5.8	2.0	8.7	2.1
4 year age group													
M.	4	11.5		10.2		12.0		10.2		12.0		11.6	
F.	5	11.9		10.6		10.0		10.3		11.0		10.9	
T.	9	11.7	4.7	10.4	3.0	10.9	3.3	10.3	3.9	11.4	2.9	11.2	4.2
5 year age group													
M.	3	18.6		17.4		16.3		16.4		15.6		14.9	
F.	6	11.7		12.2		12.5		13.8		9.4		12.4	
T.	9	14.0	5.3	13.9	3.6	13.7	3.4	14.7	2.6	11.5	3.5	13.2	1.8
6 year age group													
M.	4	17.0		14.6		13.2		14.5		16.5		16.1	
F.	2	13.0		13.0		16.8		16.1		16.4		16.2	
T.	6	15.6	2.2	14.0	3.3	14.4	3.2	15.0	2.2	16.4	2.7	16.2	2.2
All ages													
M.	13	14.0	5.2	13.0	4.2	12.3	4.4	12.1	4.5	13.5	4.8	13.6	3.2
F.	17	9.9	5.2	10.0	4.9	10.6	4.6	12.1	5.3	9.6	4.0	11.3	3.5
T.	30	11.7	5.7	11.3	4.7	11.3	4.6	12.1	5.0	11.3	4.4	12.3	3.8

SEX	NUMBER	TEST 6 Av.	6 S.D.	7 Av.	7 S.D.	8 Av.	8 S.D.	E1 Av.	E1 S.D.	E2 Av.	E2 S.D.	AVERAGE OF ALL TESTS
3 year age group												
M.	2	8.0		12.8		9.6		9.9		9.2		8.4
F.	4	7.5		8.0		9.1		8.1		8.8		6.5
T.	6	7.7	3.5	9.6	3.1	9.3	2.7	8.7	1.4	8.9	2.2	7.2
4 year age group												
M.	4	13.2		13.2		12.9		12.6		13.0		12.0
F.	5	8.4		12.2		10.3		12.2		12.8		11.0
T.	9	10.6	4.4	12.7	3.1	11.5	2.5	12.4	2.3	12.9	1.5	11.4

TABLE 2—*Concluded*

SEX	NUMBER	TEST										AVERAGE OF ALL TESTS
		6		7		8		E1		E2		
		Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	
5 year age group												
M.	3	17.0		19.4		17.7		16.5		17.4		17.0
F.	6	11.6		12.0		13.4		12.2		14.6		12.3
T.	9	13.4	3.3	14.5	3.7	14.8	2.8	13.6	2.6	15.5	2.1	13.9
6 year age group												
M.	4	16.1		15.2		16.6		16.6		16.8		15.7
F.	2	16.4		12.5		13.2		15.6		16.2		15.0
T.	6	16.2	1.5	14.3	2.0	15.5	1.9	16.2	1.7	16.6	0.8	15.5
All ages												
M.	13	14.2	3.8	15.2	3.3	14.6	3.3	14.3	3.1	14.6	3.3	13.8
F.	17	10.3	4.2	11.2	3.0	11.5	3.1	11.7	2.8	12.9	2.7	11.0
T.	30	12.0	4.5	12.9	3.6	12.8	3.5	12.8	3.2	13.6	3.3	12.2

RESULTS

Reliability of test

The reliability of the moving target test was computed in the following ways:

1. The sum of the 5 odd numbered throws on the initial test for each child was correlated with the sum of the 5 even numbered throws. The correlation obtained by using the product-moment method, for 60 children in age groups three to six inclusive, was .89 ±.17. When stepped up by the Spearman-Brown prophecy formula the reliability coefficient for the whole test became .94. This coefficient was obviously affected by the age range of the children considered. In order to throw some light on the influence of the age factor, coefficients were computed between the sum of the odds and the sum of the evens as before but first for three and four year old children taken together and then for five and six year old children together. The coefficient obtained for 30 children in age groups three and four combined was .76 ±.05, which stepped up for the whole test became .86. The coefficient obtained for the 30 children in age groups five and six combined was .63 ±.07, which stepped up for the whole test became .78.

2. The average scores for the initial test of 30 children in age groups three to six inclusive were correlated with the average scores on the first practice test, given approximately one week later. The coefficient of reliability obtained by this method was .74 ±.06.

Effects of practice on average scores

The average scores of the 30 children in the practice group for the initial, practice and end tests are given in table 2 for age groups separately and

combined, and for sex groups for each age group and for all ages combined. A score of an individual was the average of the scores made on 10 throws at the target on one day's test period. The scores of individuals on all tests ranged from 0 to 20.6. Standard deviations are given in table 2 for the practice group for each age group and for all ages combined, and for total sex groups. Table 3 is similar to table 2 and gives the data for the control group. Figure 2 shows the average scores for the practice group as compared with the control group. It also shows separate curves for the practice group boys, and the control group boys, the practice group girls, and the control group girls.

TABLE 3

Average scores on moving target test, control group

SEX	NUMBER	TEST I Av.	TEST I S.D.	TEST E1 Av.	TEST E1 S.D.	TEST E2 Av.	TEST E2 S.D.	AVERAGE OF ALL TESTS
3 year age group								
M.	2	8.7		9.2		9.6		9.2
F.	4	3.8		7.4		7.5		6.3
T.	6	5.4	5.5	8.0	3.5	8.2	2.6	7.2
4 year age group								
M.	4	11.0		12.4		12.0		11.8
F.	5	11.2		11.8		12.5		11.8
T.	9	11.2	5.2	12.1	2.4	12.3	3.1	11.8
5 year age group								
M.	3	15.4		15.1		15.5		15.3
F.	6	11.3		12.4		13.8		12.5
T.	9	12.6	2.6	13.3	2.9	14.4	2.3	13.4
6 year age group								
M.	4	18.4		18.6		16.8		17.9
F.	2	14.8		14.6		15.9		15.1
T.	6	17.2	1.9	17.2	2.2	16.5	1.4	17.0
All ages								
M.	13	14.0	5.3	14.4	4.2	14.1	3.6	14.2
F.	17	9.9	5.1	11.3	3.7	12.2	3.5	11.1
T.	30	11.7	5.6	12.6	4.0	13.0	3.7	12.4

Total groups. Tables 2 and 3 and figure 2 show that both the practice and control groups made small gains in average scores from initial to final tests and that the gain of the practice group was slightly larger than the gain of the control group. The average of each group on the initial test was 11.7. The final average of the practice group was 13.6, a gain of 1.9; the final average of the control group was 13.0, a gain of 1.3. The practice group thus gained 0.6 more than the control.

The formula for the standard error of a difference between correlated measures,

$$\gamma \text{ Diff.} = \sqrt{\gamma^2 \text{Av. } 1 - \gamma^2 \text{Av. } 2 - 2\, r_{12}\, \gamma \text{ Av. } 1\, \gamma \text{ Av. } 2},$$

was used to determine the statistical significance of the gains of the practice and control groups. By this formula the gain of the practice group was 1.9 with a standard error of 0.60 and the gain of the control group 1.3 with a standard error of 0.73. The gain of the practice group was thus 3.2 times the standard error and may be considered significant. The gain of the control group was only 1.8 times the standard error—not statistically significant.

The standard error of the difference in gains of the practice and control groups computed from the formula

$$\gamma \text{ Diff. in gains} = \sqrt{\gamma^2 \text{gain } 1 + \gamma^2 \text{gain } 2}$$

was 0.95. The obtained difference of 0.6 is not therefore significant by the usual criterion that the obtained difference must be three times its standard error in order to be considered statistically significant. The difference in the gains of the 2 groups on the first end test also is not significant because the obtained difference in gains was but 0.2.

The average score for all tests combined was 12.2 for the practice group and 12.4 for the control group. This lower average for the practice group was due to the fact that their average fell below the initial test average on practice tests 1, 2 and 4, as indicated by figure 2. The individual records show that 17 practice group children gained in scores from the initial to the

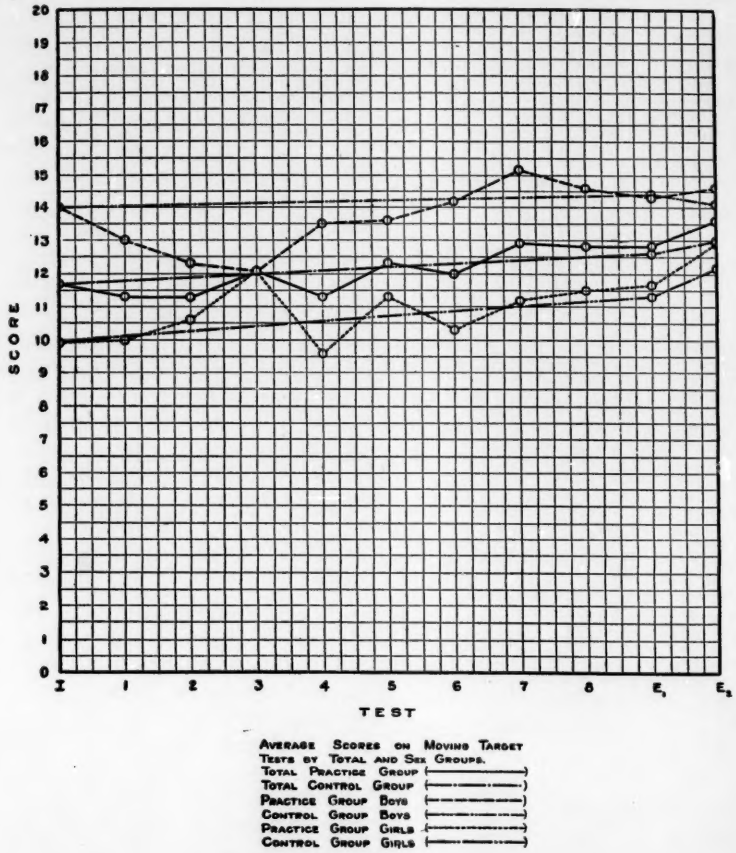

FIG. 2

final test while 13 lost; 16 control group children gained, 13 lost and 1 did not change.

Sex groups. The practice and control group girls, all ages combined, each had an initial test average of 9.9. On the final test the practice group gained 3.0 and the control group 2.3, a difference in gains of 0.7 in favor of the practice group. The difference on the first end test was but 0.4. The curve for the practice group fluctuates from test to test. It is difficult to account for the high peak on test 3 when an average of 12.1 was made, an average not made again until the final test. The drop to an average of 9.6 on test 4 is due to the drop of the five-year-old girls. Five of the 6 girls in this group made lower scores than on test 3 but the only large drop was in the case of one child who dropped from 19.3 to 8.3, due to the adoption of an inhibited style of throwing.

The initial test scores of all boys of the practice and control groups was 14.0 for each group. On the final test the practice group gained 0.6 and the control 0.1, a difference in gains of 0.5 in favor of the practice group. On the first end test the control group surpassed the practice group by 0.1. On test 3, which was a high peak for the girls, the boys' average of 12.1 was their lowest average score. This was the same average as that of the girls for the same test. The highest average, 15.2, was made by the boys on test 7.

Comparing the average scores of the boys and girls for all tests combined given in tables 2 and 3, it is seen that the boys surpassed the girls at each of the four age levels in both the practice and control groups except in the four-year-old control group in which the averages of the boys and girls were the same. These consistent differences indicate that the boys excelled on this test. The evidence that the boys excelled is even stronger when the average age in months for each age group is considered. In each age group of the practice and control groups, except the five-year controls, the boys were 0.7 to 4.5 months younger.

Age groups. Figure 3 shows the averages by age groups, for the practice and control subjects. The three-year age groups of the practice and control groups made the lowest average scores on all tests but made the largest gains from initial to final tests. The gains for each age group were as follows: three-year practice group 4.6, control, 2.8; four-year practice group 1.2, control, 1.1; five-year practice group 1.5, control, 1.8; six-year practice group 1.0, control, −0.7. Thus the three, four and six-year old practice groups exceeded the control groups whereas the opposite was the case with the five-year-old group.

Comparing the age group average scores on all tests combined in tables 2 and 3 it is seen that the average of the three-year-old practice and control groups was the same, the control excelled 0.4 in the four-year group, the practice group, 0.5 in the five-year group, and the control group, 1.5 in the six-year group. The lower averages of the practice groups were due to test periods in which the averages fell below the initial and final test averages.

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The combined gain of the three and four-year-old practice and control groups was 2.22 with a standard error of 0.88. The gain of the five and six-year-olds was 1.02 with a standard error of 0.56. The difference in gain between the 2 groups was 1.2. The standard error of 1.04 indicates that the difference is not statistically significant.

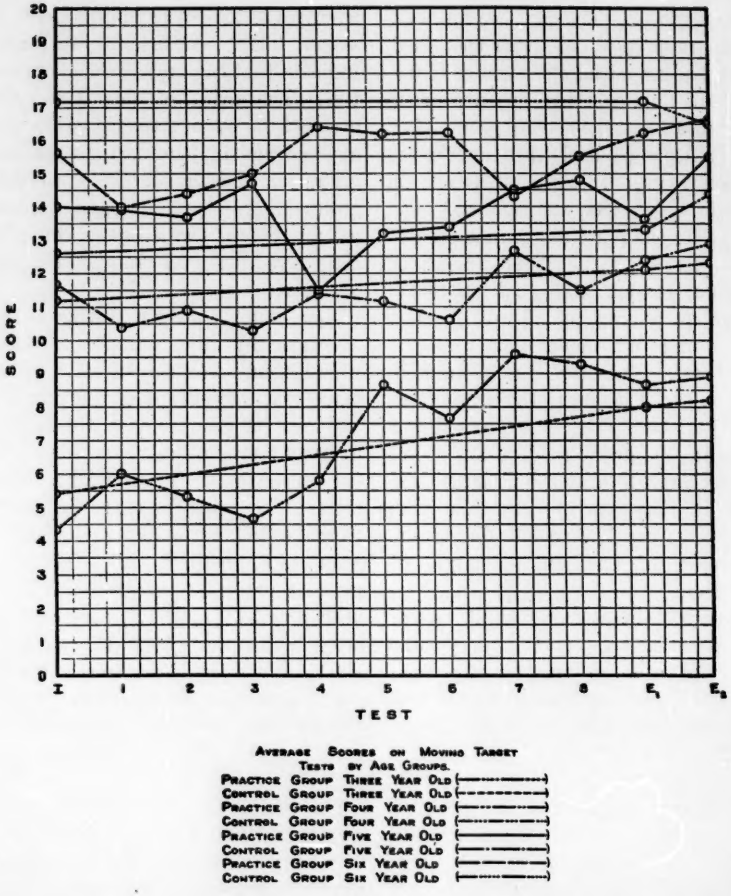

FIG. 3

Variability of groups

Coefficients of variability were high for both the practice and control groups due to large standard deviations. There was a consistent tendency, however, for the coefficients to

become smaller on later tests, showing that the scores of individuals in the groups became more closely bunched. No significant difference in this tendency existed between the practice and the control groups.

The coefficient of correlation between the gains for individual scores from the initial to the final tests and the scores on the initial test was $-.78 \pm .03$. This also indicates that the scores of the individuals in the group were becoming more closely bunched.

This tendency toward bunching seems to have been due to the fact that children scoring high on the initial test made small gains on the final test as compared with children scoring low on the initial test. An examination of individual records corroborates this. For the practice and control groups combined 9 children in the upper half on the initial test gained on the final test while 21 made lower scores; 24 in the lower half on the initial test gained, 5 lost and 1 did not change. This tendency is probably due in part to the fact that the units of improvement on the scale of 0 to 25 were not equal in difficulty of attainment.

Practice effects within test periods

In order to determine the effects of practice within a test period the average scores for each of the 10 trials of the test period were computed. Table 4 gives the results for the practice and control groups separately.

An examination of the averages in table 4 discloses that the average scores of the sixth to the tenth throws are slightly higher than the first to the fifth. The average of the first five throws of the practice and control groups combined is 11.9 and of the last five throws 12.6, an advantage of 0.7 for the last five throws.

TABLE 4

Average score by trials within a practice period for moving target test

Throw in series										
1	2	3	4	5	6	7	8	9	10	All
Practice group										
11.8	11.3	11.7	11.8	12.3	12.0	12.8	12.2	12.4	13.1	12.1
Control group										
11.9	12.6	11.2	13.1	12.0	11.7	13.1	13.0	12.8	13.0	12.4

Another indication that there was some practice effect within each practice period is shown by the fact that the bell was rung 102 times out of 217 on the first five throws and 115 on the last five throws.

Practice effects on elimination of errors

For the practice group 76 per cent of all throws were below the center of the target on the initial test and 62 per cent on the final test, a reduction of 14 per cent. For the control group 69 per cent of the throws were low on the

initial test and 67 per cent on the final test, a reduction of 2 per cent. There is some evidence of a greater tendency for the practice than for the control group to eliminate the low throws. However, this did not bring about a significant difference in the gains in scores of the 2 groups.

For the practice group 67 per cent of all throws on the initial test were to the left and 61 per cent on the final test, a reduction of 6 per cent. For the control group 69 per cent were to the left on the initial test and 62 per cent on the final test, a reduction of 7 per cent. There was thus a slight tendency for both groups to correct their throws to the left.

Distance target moved

The children stood facing the center of the 96 inch path through which the target might run so that it would seem that the target would be easier to hit when approximately in the center of its running path. This would be at the 48 inch mark. However, the children did not let the target move 48 inches before throwing. The average of the practice group on the initial test was 19.4 inches and on the final test 19.8; of the control, 20.4 on the initial test and 24.2 on the final test. There is no evidence that practice had any great effect on the distance the target was allowed to move.

Relation of success to other trials

In order to determine the relationship of throws that rang the bell to throws immediately preceding or following, the data were analyzed as follows: The average of all throws immediately preceding a throw which rang the bell was computed for all trials in the day's series for the children in the practice and control groups combined. Similar averages were computed for all throws immediately following the ringing of the bell. The averages of all throws not ringing a bell and not just preceding or following a throw which rang a bell was 13.5. The average of all throws immediately preceding the ringing of a bell was 14.6 and the average of all throws immediately following the ringing of a bell was 15.2. The difference between the average scores of the throws not ringing a bell or not immediately preceding or following a throw which rang a bell, and the average of the scores immediately preceding the ringing of a bell was 1.1 with a standard error of 0.47. The difference between the average scores of throws not ringing a bell or not immediately preceding or following the ringing of a bell, and the average of scores immediately following the ringing of a bell was 1.7 with a standard error of 0.41. Both obtained differences are large in relation to their standard errors and are probably not chance differences.

There is evidence, then, that the throw striking a bell was affected by the throws immediately preceding it and in turn influenced the throw immediately following it. The throw ringing the bell was probably affected by the practice preceding it and especially by the practice on the throw immediately preceding. In like manner the throw ringing the bell probably had its greatest carry-over to the throw immediately following. This may have been due partly to the factor of

motivation which would probably function best immediately after throws which either hit the bell or came very close to it.

Manner of throwing

Children differed strikingly in their styles of throwing. Each child also often varied his style in various ways. Some of the variations were as follows: hand used; manner of holding ball; movement of parts of the body such as the hands, arms, shoulders, trunk, legs and feet; force of throw; position of the child.

In both the practice and control groups 96 per cent of all throws were with the right hand. A few children of all ages occasionally threw with the left hand but no child threw exclusively in this way. One boy in the three-year-old practice group and one girl in the five-year-old control group were the only children who made at least half of their throws with the left hand.

Records were kept whether throws were overhand, underhand, toss, or miscellaneous. A throw was considered overhand if the hand was brought forward above a plane horizontal with the elbow; below this plane, it was considered an underhanded throw unless the arm was not bent in delivering the ball, which was considered a toss. Miscellaneous throws included peculiar styles of delivery such as pushing the ball from the waist with both hands and throwing from the waist outward. The per cent of the various styles of throwing for the practice and control groups combined was as follows:

SEX	CASE	THROWS	OVERHAND	UNDERHAND	TOSS	MISCELLANEOUS
Girls	34	2380	88.8	3.4	6.6	1.2
Boys	26	1820	87.1	11.9	0.5	0.5
Total	60	4200	88.0	8.1	4.0	0.9

It is seen that 88 per cent of the throwing was overhanded.

Relation to intelligence

The correlation of the scores on the initial test on the moving target with mental age for 59 children ages three to six was .56 $\pm$.09. When chronological age was partialed out the correlation was reduced to .05 $\pm$.09. Apparently skill in throwing at the moving target had little relation to intelligence as measured by tests.

SUMMARY

The purpose of this investigation was to study some aspects of the development of motor coordination in young children. The objective was to discover the effects of systematic well motivated practice upon the ability of young children to hit a moving target with a ball. Two groups of children of 30 each, ages two and one-half years to six and one-half years, were equated upon the basis of their initial performance on a moving target test. The practice group repeated the test once a week for eight weeks. At the end of this period the practice and control groups repeated the test twice on successive weeks. Three other motor tests were given, once at the

beginning and again at the end of the experiment.

From an analysis of the data for composite groups on the moving target test, the following are some of the more pertinent results:

1. Both the practice and the control groups made gains in average scores from the initial to the final tests. The gain of the practice group was larger than the control group but the difference in gains was not statistically significant.

2. In the practice group 17 children gained and 13 lost in scores from the initial to the final test. In the control group 16 gained, 13 lost and 1 did not change.

3. The boys made larger average scores than the girls in the different age groups.

4. Younger children made lower average scores on the test but made larger gains from the initial to the final test.

5. The variability of the scores of both the practice and the control groups decreased greatly from the initial to the final tests.

6. There was evidence of practice effects within each test period as the average of the last five throws was higher than the average of the first five in the series of 10 throws.

7. Both the practice and control groups tended to correct their throws when they were too low but not when they were too far to the left.

8. Practice did not affect the distance the children allowed the target to move before throwing.

9. The averages of scores on throws immediately preceding or following a throw which rang a bell were higher than the average of the scores for other throws in the series.

10. Ninety-six per cent of all throws were with the right hand.

11. Eighty-eight per cent of all throws were overhanded.

12. The correlation of the initial scores and mental age, with chronological age partialed out, was $.05 \pm .09$.

Two comparable groups of children increased in skill in hitting a moving target with a ball over a period of three months. However, the group which was given specific practice throughout this period of time did not improve significantly more than the group which was not given practice other than on the initial and final tests. These results indicate that the improvement in skill did not result primarily from specific practice but from other factors such as structural maturation and general practice which had a direct bearing on the specific skill.

No attempt was made to differentiate the relative effects of each of the factors other than specific practice on the increase in skill. However, in the present tendency to emphasize the rôle of structural maturation in learning we should not overlook the importance of practice on the relatively simpler skills which are utilized in performing a complex skill. The children employed in this study practiced many coordinations of body, eye, arm, hand and leg movements in their ordinary daily activities which were utilized in the complex skill of hitting the moving target.

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The Galvanic Skin Reflex in Infancy

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ACCORDING to investigations by Peiper (2), the galvanic skin reflex in human infants is undeveloped until the age of about twelve months. Its absence in early infancy cannot be due to immaturity in the effectors, for the cutaneous organs concerned in the reflex are apparently anatomically and functionally well developed. Nor can it be assigned to a deficiency in the receptors nor in the centripetal pathways, for skeletal muscle reactions can be elicited by the same stimuli which are ineffective in producing a G.S.R. Peiper finds his results consonant with the theory of vagus dominance in infants, and concludes that the reflex arcs concerned in the G.S.R. are incomplete either centrally or in the efferent thoracico-lumbar pathway.

Results[1] obtained by the writer with each of 8 infants, three to eleven months of age, are at variance with those reported by Peiper, and appear to demand a reconsideration of his theory. The galvanometer used in the present experiment was a simple moving coil instrument (D'Arsonval, manufactured by E. Roger, Paris) with a Wechsler (6) circuit. The galvanometer was connected across a Wheatstone Bridge, the subject and a milliammeter being in series in the fourth arm of the Bridge. With infants it is of course impossible to use cup electrodes, and as a substitute a bandage type of electrode was employed, consisting of two pieces of silver foil, 2 cm. square, which were soldered to the wires leading from the fourth arm of the Wheatstone Bridge. In order to prevent battery action at the solder junctions, these were covered by a flexible and moisture-proof wax preparation. The foil electrodes were sewn into pockets of soft fabric, covered with kaolin and saturated with normal saline; the moist clay forms a paste which adheres to the skin, and avoids resistance fluctuations from changes in the skin contact.

The usual procedure was to bring the child into the laboratory at 8:00 a.m., which proved to be the most favorable time for observation in infants of this age; usable records, however, were also obtained in the later morning and in mid-afternoon. The electrodes were attached to the right foot, one to the sole under the instep and the other to the calf of the leg. The child was placed in a comfortable position on a couch, out of sight of the experimenter and of the apparatus employed to produce stimuli and to record responses. A reflection system focused a beam of light from the galvanometer mirror upon a zero position on a kymograph (fig. 1). Current was now passed through the potentiometer until a standard reading of 0.1 milliam-

[1] An investigation made at the Institute of child Welfare, University of California.

peres was obtained on the milliameter in series with the subject; a deflection of the light occurred, of course, at the same time. The Wheatstone Bridge was adjusted to bring the deflection back to zero, and the subject's initial resistance could then be read from the dials. For the remainder of the experiment, the milliameter reading was maintained as constant as possible at .05 m.a. A standard schedule of stimuli was used, including visual, auditory, thermal, and electro-tactual stimuli, their duration and intensity being controlled by a system of switches and rheostats. The recording drum consisted of a continuous roll kymograph, calibrated for seconds, and moving at a constant rate of six inches a minute. The resistance line was traced by hand instead of photographically, although in some cases photographic records were also obtained. The manual method has the advantage

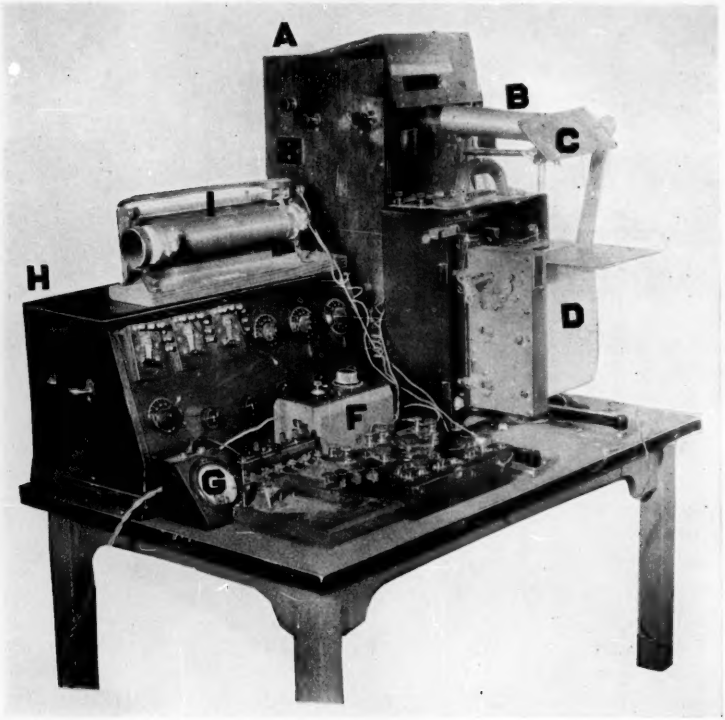

FIG. 1

A, galvanometer housing; *B*, light tube; *C*, stationary mirror; *D*, kymograph; *E*, Wheatstone Bridge; *F*, potentiometer; *G*, milliameter, *H*, stimulus control box; *I*, supplementary rheostat for Bridge.

of keeping the experimenter closely in touch with the subject's reactions, and makes it possible to note down accessory records, in symbol form, at the appropriate places beside the resistance line. In the case of responses which have such a slow latent time as the G.S.R. (one and one-half to three or more seconds) even an untrained person finds no difficulty in accurately following the resistance line. In order that the infant's overt behavior might be compared with the galvanometric data, a second observer took a detailed record of bodily movements, changes in facial expression, flushing, overt respiratory changes, and vocalizations.

Records were obtained for 60 experimental periods of about thirty minutes each. In the case of 1 infant, repeated observations were made each week from her sixth to her ninth month.

No difficulty was found in obtaining galvanic responses from infants even as young as three months. The most effective form of stimulation was electro-tactual, through electrodes attached to the arm or the left leg. In administering the current an attempt was made to adjust the intensity (through a rheostat introduced into the secondary circuit of a Porter inductorium) so that it would be strong enough to produce a G.S.R., but too weak to result in crying or overt movements. This differentiation proved to be readily possible, although with some subjects it was necessary to guard against summative effects of stimulation. Next to mild pain stimuli, the most effective agents were loud sounds. All of the subjects showed a marked response upon the first presentation of a bell, buzzer or loud clang. Their overt reactions, however, were less consistent, and in several cases bodily startle reactions to loud sounds were never shown except when the infant was falling asleep. G.S.R.'s were obtained to the removal of the bottle when nursing, and to situations involving a sudden withdrawal of support. They were never elicited by visual stimuli (except after conditioning) (1), by conditions involving relief, nor by any forms of stimulation which would ordinarily be described as "pleasant."

In comparing the results from infants with those obtained for 45 adults and for 40 nursery school children,[2] under similar instrumental and stimulation conditions, the following points may be noted:

1. In its basic characteristics, the G.S.R. is similar to that found in older subjects. This applies to the phenomena of (a) latency (typically from two to three seconds) (b) the parameter of deflection (fig. 2) (c) specific negative adaptation (except for definitely nocive stimuli), and (d) specific recovery after an interval.

2. The incidental phenomena are similar: (a) the curve of rest (a stabilization process at the beginning of the experiment, involving usually a steady reduction in resistance (5), (b) the Vorausschlugphänomen (5) (an initial small reverse deflection sometimes occurring with intense stimuli) (c) the occurrence of spontaneous or secondary responses after intense stimulation ("Doppelschwankungen")

[2] The results for the nursery school children are in process of preparation. The data for adults have been reported, in part (7).

and (d) characteristic resistance changes in respiratory reactions, as in sighing. An inverse relationship was shown to overt movement; stimuli which produced an inhibition of arm-leg movements frequently gave a marked G.S.R., while stimuli of an intensity to produce crying or thrashing movements were often followed by a diminution or extinction of the G.S.R. This is in essential agreement with results for adults, reported by Prideaux (3). In certain cases, spurious resistance changes were sometimes effected by pressing the foot on the bed or against the other foot and thus altering the electrode contact. Deflections due to this cause could readily be recognized, not only through their concomitance with activity, but also through their abruptness and rapidity. In rare cases it became necessary to immobilize the leg by holding it just below the knee.

3. The initial resistance tends to be lower in infants than in adults. Only about 5 per cent of the adults showed resistances as low as 8000-10000 ohms, which was average for the infants.

4. No change in resistance was noted in relation to sleep or waking. This is in disagreement with Richter's (4) report to the effect that a rise in resistance occurs in adults during sleep; the disagreement probably cannot be accounted for in terms of the points of attachment of the electrodes. On 8 different occasions characteristic psychogalvanic responses (to sounds) were obtained during sleep; these were usually, but not always, of a diminished magnitude.

5. As in adults, the most effective stimuli are those which involve "startle," or "frustration," and which are commonly regarded as associated with the emotional states of fear and anger. For these stimuli, the intensity threshold is higher than is usually found for adults. It is possible that Peiper's failure to obtain the G.S.R. in infants was due to the use of stimuli of too weak intensity; his record of procedure is too meager to permit judgment on this point. Correlated with the fact of high threshold, is the fact that the magnitude of deflection tends to be smaller than under similar conditions with adults.

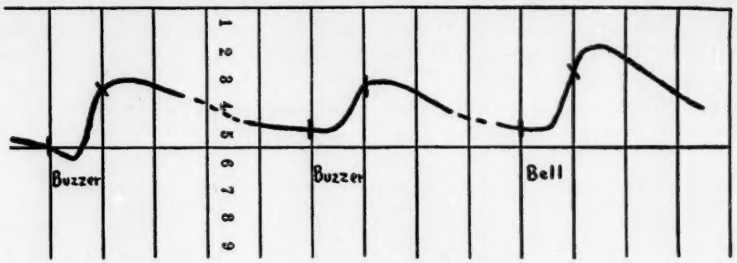

FIG. 2

These results unquestionably demonstrate the functional completeness of the arcs involved in the galvanic skin reflex, at least as early as three

months of age. The fact that the G.S.R. in infants is smaller and less easily aroused than in older children, can no doubt be explained in terms of the relationship between overt and visceral expression. If this relationship were always positive, our instrumental records would show an increase in visceral activity accompanying the more external signs of disturbance. In so far as the galvanometer, however, may be taken as indicating visceral changes, our evidence points in another direction. Children who are the most ready to cry are frequently the least reactive on the galvanometer; in such subjects, when G.S.R.'s do occur, they may be diminished or eliminated by an intensification of the stimuli, with resulting crying or bodily movement. The quick transition in emotional tone, so often exhibited in young children, is probably a further indication of the "surface" character of their emotions, and of a lack of persisting visceral reinforcement. In older children the increase of inhibition and of apparent emotional control may imply (with reference to certain stimuli) merely a shift from outer to inner patterns of response. When a direct outward release is blocked, the condition of the organism appears to be favorable to a heightened visceral discharge, one expression of which is provided by the galvanic reflex. Thus the characteristic features of "infantile" emotional behavior may be related to the stage of development of those mechanisms which are concerned in determining the proportions of somatic and of visceral discharge.

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The Orientation of Plane Figures as a Factor in Their Perception by Children

CHARLOTTE RICE

HISTORICAL

IF ONE were to limit a review of the field of perception to material which concerns the specific problem in hand, i.e., the orientation of plane figures as a factor in their perception by young children, practically nothing would be cited except the following general statement made by Stern in describing the reaction of his own children to pictures:

> It has often been observed that it seems to make little difference to small children whether a picture is put before them right way up or upside down. . . . The older the child, the less of this indifference to the position of the picture; and in any case it varies very much with individuals, for there are children in whom it has not been observed at all. (19)

He cites careful observations of this indifference in his own children at the ages of one year seven and one-half months and three years five months, and explains the recognition and production of pictures upside down by the supposition that the idea of form and the idea of position are two distinct psychic functions, the second of which is only developed by a somewhat slow process of learning. To this report may be added the proverbial surprise of parents upon discovering that a child's enjoyment and comprehension of a picture is in no way altered by the position in which he sees it.

But such data merely serve to indicate the existence, without limiting the ages, of a period in the life of the child when the position of a picture in no way affects his attitude toward it, followed by a period in which the orientation, when normal, helps, and when abnormal, hinders the comprehension and appreciation of the material presented to vision. Such a limitation was the purpose of the experiment here presented.

The three fields of imitative drawing, of recognition of similar forms, and of color and form preference in perception encroach so closely upon this one, however, that a preliminary review of the work done in them will be of sufficient interest to be worth while. Also more general deductions concerning the development of visual perception in children are constantly being made in other connections, such as the conclusion by Oppenheim (18) that a child comes to associate visual impressions with the proper relations of the object in space only in the most gradual way, and that this difficulty together with a limited power of accurate observation is bound to make his reports of events unreliable. Cramaussel (4), in evaluating reports from

children three to six and one-half years of age concerning what they see on a postage stamp, concludes that as age advances, the specific takes the place of the vague and general in the response, confusion gives place to well defined limits, and enumeration gives way first to description and then to analysis. Such generalizations reflect the obvious fact that the development of perception is a gradual process, without limiting the steps involved. For the latter we must turn to the more specific experimental work.

The responses in imitative drawing are peculiarly limited. Always the child tends to draw what he knows rather than what he sees. For spontaneous drawing this is quite satisfactory, because he is under no obligation to finish the picture he starts. But for imitative drawing, which is rarely attempted at early ages except under experimental conditions, this tendency and the child's ready suggestibility make it difficult for him to persist in the task until it is completed, and frequently failure to copy even simple forms may go with a considerable degree of creative ability in spontaneous drawing.

In 1911, Van Gennep (22) reported unrecognizable attempts on the part of his 5 year old daughter to copy outline drawings of simple objects and printed letters. The pictures, having more meaning to the child, were more like the copies than the letters, though the latter were simpler of execution.

Huth (11), in 1914, experimenting with 37 kindergarten pupils averaging four and one-half years of age, to see whether they were ready to receive instruction in writing, concluded that children of this age show little ability to copy meaningless combinations of lines. Work of more recent date on a comparable group of subjects was done by Gates and Taylor (8) in 1923, and Hertzberg (10) in 1926, on methods of teaching beginners to write. In these studies it was found that the method of copying directly from the model was both harder to learn and less interesting to the child than any of the various methods of tracing used.

Another section of this field is that of mirror writing, an anomaly which had been associated up until about 1902 almost entirely with cases of mental disorder or paralysis affecting normal motor coördination. But in 1909, Stern (20) reported mirror drawing and writing as a natural phenomenon in young children especially in imitative drawing. When, according to Stern, at four years, children begin to outgrow scrawling and make real forms, there appears, at first, little perception of position. The frequent easy use of the left hand at this period is often accompanied by mirror writing, and the tendency to watch the progress of an older brother or sister from across the writing table, and to imitate the observed motions, is a very frequent source of the development of reversed writing and drawing. E. Sz. at five years, copied from his brother in this manner, using his left hand, and learned his letters so well that he could write anything that was spelled to him. Later, he began suddenly and apparently without external urging to form his letters in the normal positions and order, still using his left hand, and finally, just as spontaneously, and

before he had reached the age of seven, he shifted from the left to the right hand, still maintaining the normal position and order of the letters. Stern cites similar cases, reported by Ballet, Degallier, Kerschensteiner, Maurer and Albien.

Two instances of a strikingly similar nature occurred in the Child Institute of the Johns Hopkins University last year. In one case, both the right and left hand were used in drawing, and the motions in the left hand were nothing less than a right to left reversal of those in the right. In the other case, the right hand alone was used, but many of the letters were formed backwards. In neither case did the child see anything exceptional in his result. Indeed, many adults who have not been trained to care in writing and printing show reversals of this nature,—as a hasty survey of "no trespassing" signs in any rural section of the country will show.

In 1913, Paula Meyer (17), in various experiments, under different conditions, but all designed to show a comparison between the child and the adult in the ability to reproduce figures from memory, found a consistent tendency for a certain percentage of reversal and inversion. The children used in the experiments were seven years old or older, and they showed a 51 per cent tendency to neglect orientation, as against a 39 per cent tendency on the part of the adults.

On the abnormal side, Downey (6) describes a case in which mirror writing, persisting into adult life was associated with general motor disorientation, and Hornig (7) finds dislocations in writing and drawing combined with speech defects in elementary school children. Other cases in which the phenomenon is found along with pathological conditions are described by Abt (1) and Laprade (16).

It is evident from the above that orientation of the figure or letter seems to mean very little to a child who is just beginning to imitate in his drawing and writing. Whether a similar condition occurs generally with reference to a child's comparison of objects with regard to their similarity or difference, will be brought out, it is hoped, by the present experiment.

In the field of recognition of similar forms, much seems to depend at the outset on the child's ability to comprehend the significance of the terms "like" and "different." The results of an experiment by Jones (12) in 1925 seem to indicate that in general the judgment of difference develops sooner than that of similarity. In dealing with geometrical forms or familiar outline figures, the complication of language development is to a large extent removed, but the importance of the comprehension of these two terms remains.

In 1913, Koch (14) employing a simplified form of Gruenbaum's (9) method found that the performance scores for the recognition of like elements in two figures increase from 22 per cent perfect to 64 per cent perfect among the boys from the first grade to the eighth, and from 25 per cent perfect to 63 per cent perfect among the girls, about 60 per cent of this gain occurring during the first four grades. When the recognition and localization of the unlike figures is included, the

girls reach in each grade, only about two-thirds the ability of the boys. In 1920, von Kuenburg (15) extended this work to children between the ages of three years six months and six years six months. Her figures substantiate those of Koch to a large extent.

In 1913 and 1914, in experiments devised to demonstrate the relative preference for form or color in matching figures, Katz (13) and Descoudres (5), conluded that the perception of form develops later than that of color. But when Buehler (3) and von Kuenburg (15) altered the conditions of the problem to include the processes of building with blocks, or fitting covers on boxes, they found that the choice according to form was preferred.

In 1927, Tobie (21) concluded from a combination and revision of these experiments that up to the age of three years, eight months, there appears a phase of early development in which the reaction to form or color is dependent not on the central conditioning, but on the intensity and vividness of the factors themselves. Above this, the child is conditioned on constitutional grounds to prefer color, gradually shifting over to form preference at about five years.

In 1929, Brian and Goodenough (2), repeating and modifying the Descoudres experiment, found form preference at all times up to the age of eight years except between the ages of three and six years, when color gradually rose to a peak and subsided again.

From the above it is evident that the development of form perception is gradually beginning to appear significant about the age of five years. While none of the experimenters have defined the term perception—many of them avoiding it completely—there seems to be a general consensus of opinion that it refers to a certain type of reaction to sensory stimuli distinguished by a more or less well developed ability to discriminate—perception and discrimination growing in a parallel course. It is in such a sense that the term will be used in the material here presented.

It was in the course of a test for the discriminatory recognition of the diamond among a number of similar and dissimilar geometrical figures that the the unexpected fact was disclosed that the two oldest children of the group refused to accept as the same, two figures which were identical except for their orientation in place on the page—the long axis of one diamond being horizontal, and of the other being vertical. No such refusal, or even hesitation was noticed on the part of any other child in the group.

Since the two children in question were at the very top of the age range of the group, being five years and one month and five years and three months respectively, it was logical to surmise that they might well be on the lower limit of an age range in which the orientation of a figure entered as a positive factor in its recognition and hence in its perception. Further preliminary study on another kindergarten group the same year, in which the age range was nearly identical, led to corroboration of the previous data. The demand for a test which would determine the possible existence and limits of such an age range was obvious, and so was developed the final form of the experiment herein to be de-

scribed, as a test by which to determine, if possible, the age when a child either will, negatively, refuse to recognize "sameness" in two figures which are identical, but not in the same position on the page, or will, positively, indicate by some word or action that they would be the same if one or the other were turned part way around.

DESCRIPTION OF EXPERIMENT

A problem in visual perception is almost bound to encroach somewhat upon kinaesthetic perception, not only because of the eye movements accompanying most acts of observation, but also, in the matter of certain grosser movements of different parts of the body—noticeably the hands. The latter is especially true when the aim of the perception is later recognition or reproduction. For this reason it was decided to combine with the test of form perception 2 other types of test; one, a test of the development of motor control in handling a pencil, and the other a test presumably of the ability to combine motor control and perception in the copying of a simple line figure. By showing the relation between the degree of development of the perception of form and the ability to copy a figure on the one hand, and motor ability and the ability to copy a figure on the other, it was hoped incidentally to throw some light on the general question of the relative importance of training in perception and in motor control for the accurate pictorial representation of form.

The complete test consists of an array of 5 individual tests, 2 forms of the copying test, 2 of the perception test, and 1 of the motor control test, which are given in two test periods two weeks apart in time. During the first test period the child is presented with 3 of the 5 tests, 2 of the copying tests and 1 of the perception tests. Two weeks later, during the second test period, the child is presented with the other 2 tests, the second perception test and the test of motor control. A detailed account of the form of the tests and the experimental procedure follows.

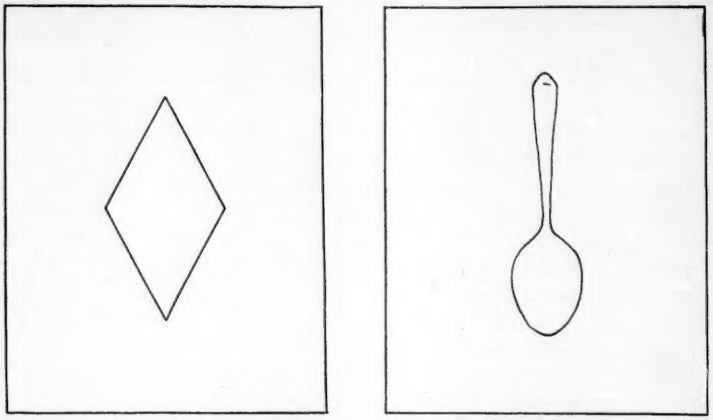
Copying Test: Drawing of Diamond from Visible Model

The materials for this test consist of a single white card 4 by 5 inches, on which is a black ink drawing of a diamond $2\frac{3}{4}$ inches (long axis) by $1\frac{1}{2}$ inches (short axis) (fig. 1, *a*). This card serves as a model in both the copying tests and in the tests of form perception. Slips of paper torn from pads 3 by 5 inches seem to furnish the most convenient form for maintaining the record of performance. The child is seated comfortably across the table from the experimenter and is shown the model card in the horizontal position with the instruction: "Do you see this (pointing to drawing, but being careful not to trace)? See what a nice picture you can draw for me that will look just like this." At the same time he is presented with a slip of paper, also in the horizontal position, and a pencil. Time is taken with a stop watch from the moment he begins to draw until the pencil is lifted after the last line. No matter what the result of the attempt, praise is given in the simple form "That's fine." When the child has finished, the experimenter takes the copy and

records on the same slip the time taken for the drawing. In cases where the production is a mere scribble, the time is taken between the beginning of drawing, and the first pause in operations or wandering of attention sufficient for the examiner to terminate matters with "That's fine" without appearing to interrupt an apparently well unified activity. This same procedure is then applied, with the model and paper both presented in the vertical position. Occasionally, if the second copy is better than the first, the form of praise is changed to "That's the best one yet." Frequently it is found that when the child starts to draw, especially in the cases of the younger ones, the lines suggest something other than the form he has been told to copy, and he announces that he will make you such-and-such a thing. The instructions are then repeated: "But make something that looks just as much like this as you can (pointing again to the model)." If the child says he can't, he is encouraged to try as hard as he can anyway by some such admonition as: "Oh, but everybody tries," or "But try just the best you can, anyway."

Test of Discriminative Perception: Perception of Diamonds—Vertical and Horizontal Presentation

The materials for this test consist of the model card described in the copying test, and 4 cards 8½ by 11 inches, each containing a variety of figures arranged as in figures 2 to 5 inclusive.



a. Perception of Diamond Test *b*. Perception of Spoon Test

FIG. 1. MODEL CARDS

The diamond model is placed in front of the subject in the vertical position, and the following directions are given: "Now, I have a card here with some pictures on it, and one of them looks just like this (pointing to the model). I want you to see how quickly you can put your finger on a picture on this card (pointing to

the card) which looks just like this (pointing again to the model.)" Then while laying the first card in front of the subject—"Where is one that looks just like it?" The stop watch is started at the moment the card is placed in front of the subject, and is stopped the minute the finger comes to rest on the first figure indicated. No matter what figure is pointed to, the examiner's response is simply, "All right." Occasionally, the child realizes immediately that the figure pointed to is not the correct one and points again, saying something such as "No, this." In such a case, the fact is recorded but no change is made in the time. If an incorrect figure is pointed to without change, the record is made of the figure pointed to.

Before the second card is shown, the model is turned through an angle of 90 degrees, so that the diamond is shown in the horizontal position instead of the vertical, to coincide with the position of the diamond on the second card. This is done without comment, and in the least noticeable

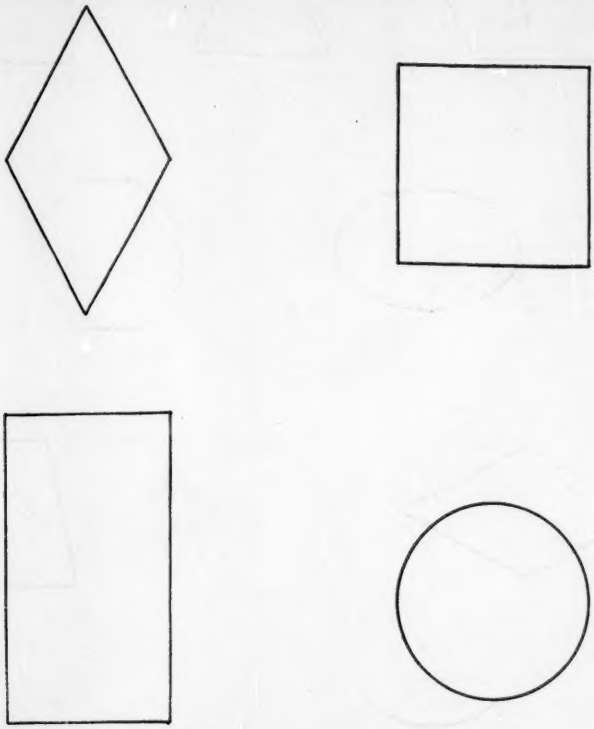


FIG. 2. PERCEPTION OF DIAMOND TEST—CARD 1

manner possible. Then the second card is shown, with the directions, "I have another card here with some pictures on it. See how quickly you can find a picture on this card (pointing to the card) which looks just like this (pointing again to the model and taking care that the child's attention is directed to it before the card is shown).)" It is found imperative to exercise great care in giving the directions for the second card so that the

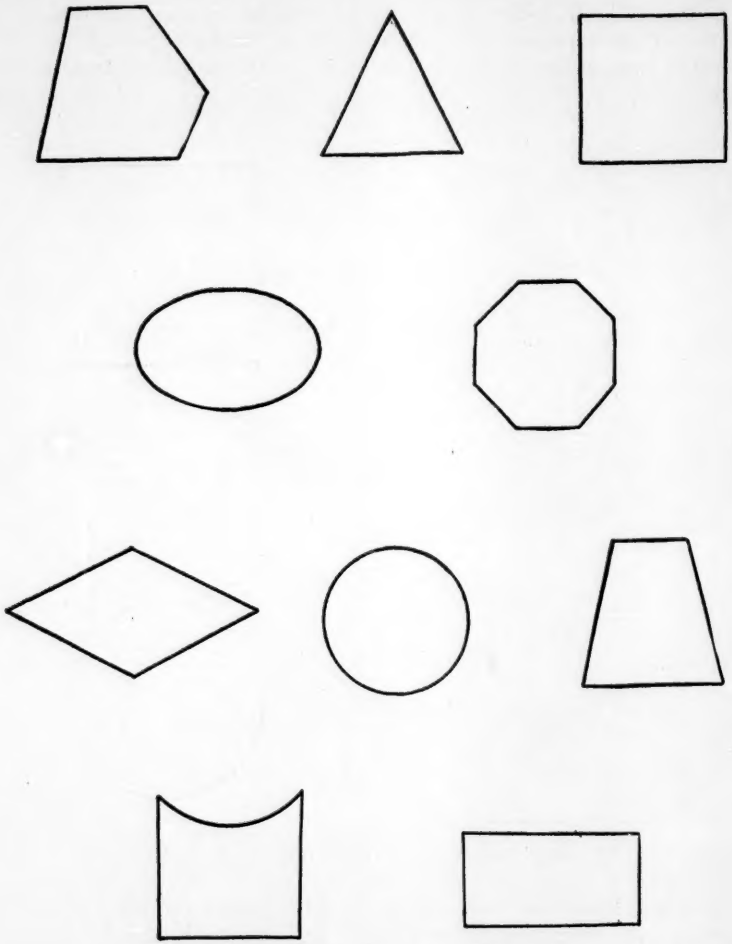


FIG. 3. PERCEPTION OF DIAMOND TEST—CARD 2

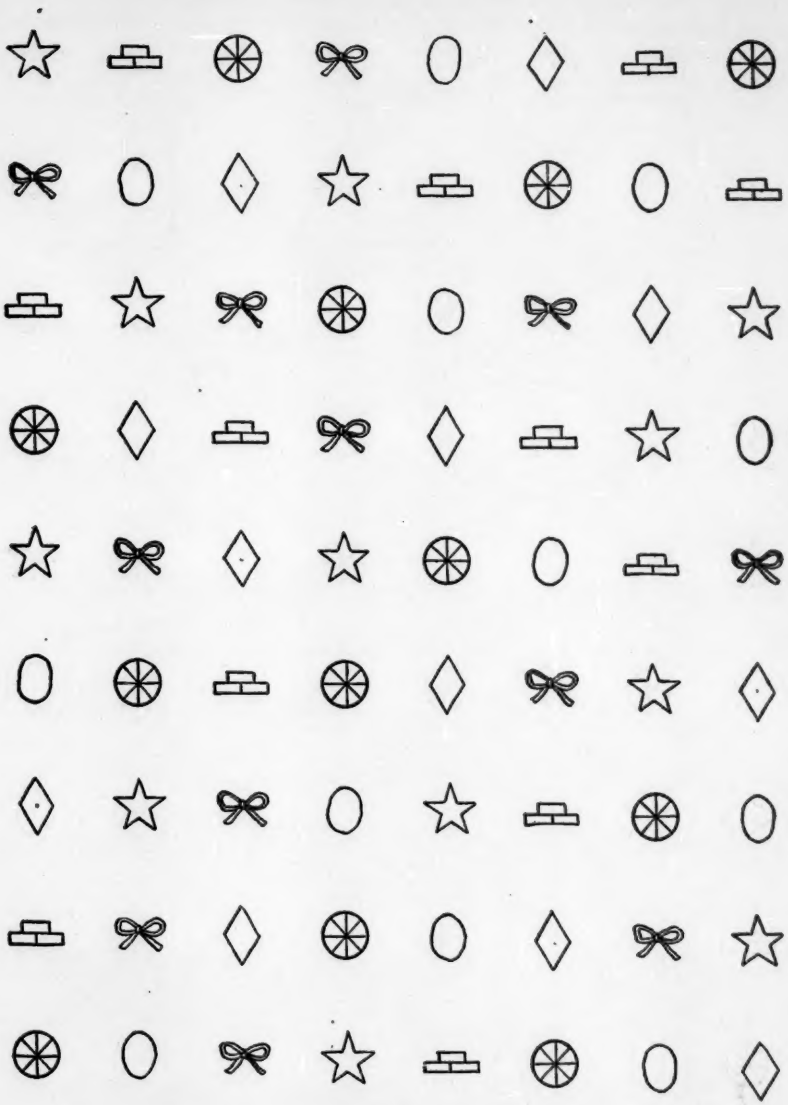


FIG. 4. PERCEPTION OF DIAMOND TEST—CARD 3

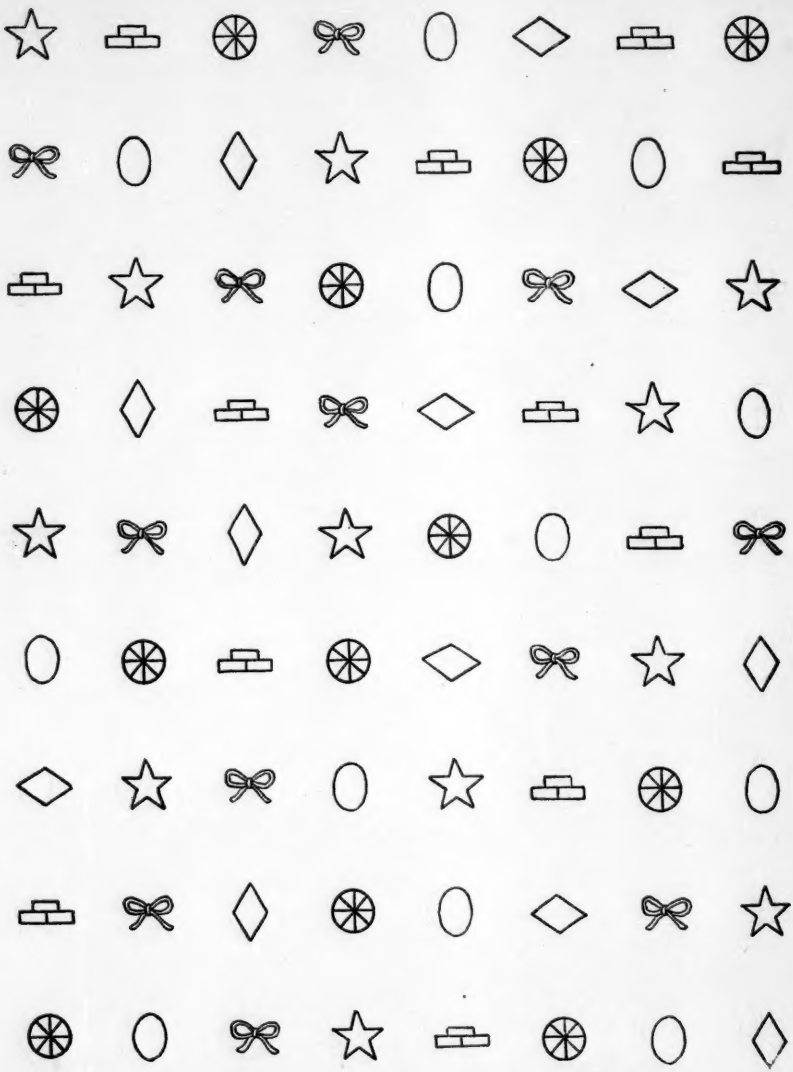


FIG. 5. PERCEPTION OF DIAMOND TEST—CARD 4

inflection of the voice on the final "this" should not betray by a rising inflection that the model was in any way different in form or position from the model as used for the first card. As in the first case, no matter what the response of the child, the experimenter accepts it with the assurance "All right."

Before the third card is shown, *no* change is made in the position of the model. In spite of the fact that the diamonds on the third card are in the vertical position, the model is left in the horizontal. The directions here are the same as for the second card, care being again exercised that the child's attention is drawn to the model before the card is shown, and that the experimenter's voice shall give no hint of the fact that there is any discrepancy between the position of the model and the diamonds on the card. If the child states that there is no figure on the card like the model, or if at the end of 45 seconds he has made no response but shows by his actions he is still searching, the model is turned into the vertical position by the experimenter with the question "Now can you find one?" Whatever the response of the child, the experimenter's response remains unchanged, "All right." Finally, with the model still in the horizontal position, the fourth card—which differs from the third only in the fact that half of the diamonds have been turned through an angle of 90 degrees—is shown with the same directions and the same care for details. Again, whatever the response of the child to the card, the experimenter accepts it as in the case of the others. On the fourth card, after the initial choice, the child is asked to point to all the figures he can find which are just like the model. No time is taken for this, and the purpose of the request is to determine whether the child is choosing one position consistently, or is pointing merely to the first one in either position which looks to him like the model.

A record is made of the time and correctness of each response, together with a memorandum of the figures substituted in incorrect responses, and a detailed account of the responses in work or action to the third and fourth cards.

Copying Test: Drawing of Diamond from Memory of Model

The material for this test is the same as that for the first copying test. The child is shown the model in the horizontal position for 10 seconds, and while he is looking, the following directions are given by the experimenter: "I want you to keep looking at this until I take it away. Soon I'm going to take it away and hide it, and then I want you to draw me a picture that looks just like it." If the child's attention tends to wander from the model while the experimenter is talking, the admonition is given to keep looking at the picture all the while. At the end of 10 seconds the model is taken away and turned over on the table, face down, while the experimenter says, "Now, I'm going to take it away and hide it, like this." Then, while placing before the child a slip of paper in the horizontal position, and giving him a pencil, the experimenter says, "Now, see what a nice picture you can draw me that looks just like

the one you have been looking at." If the child insists that he can't, he is urged to "Try anyway." No matter what the result of the attempt, praise is given in the simple form, "That's fine." Occasionally during this test, a child questions the examiner as to which position of the diamond should be drawn. In each case a non-committal answer is given such as "Draw it just as you saw it on the card." The record is taken of the time for drawing. Then the experiment is repeated, with the model and the paper in the vertical position instead of the horizontal.

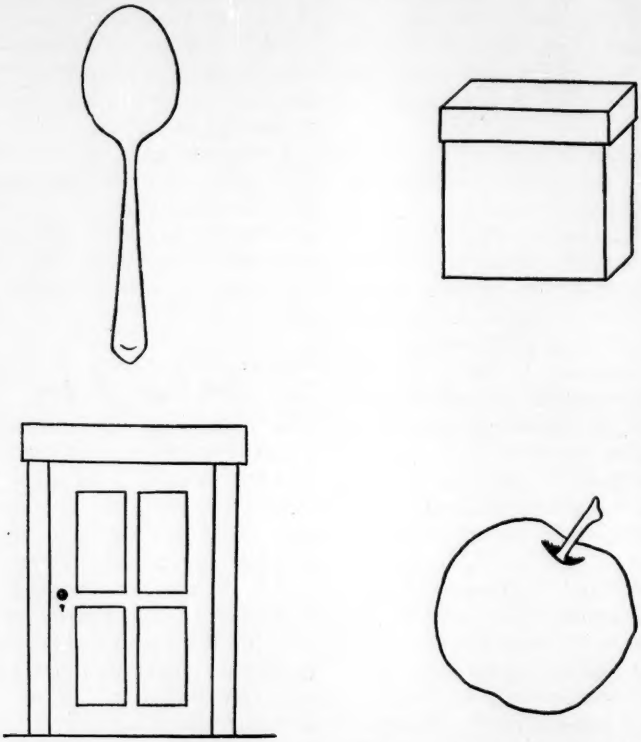


FIG. 6. PERCEPTION OF SPOON TEST—CARD 1

Test of Discriminative Perception: Perception of Spoons—Vertical and Horizontal Position

The second discriminative choice test was devised with the idea in mind that a child's response to the test might be materially altered by the degree of familiarity of the objects figured. The model in this test con-

sists of a spoon drawn to the same scale (approximately) as the model diamond (fig. 1b). The figures on the cards, instead of being geometrical forms are of objects more or less familiar in the life of the child, as may be seen in figures 6 to 9 inclusive. The directions, procedure, and record taken for this test are exactly the same as those for the test of discriminative perception in which the diamond served as the model.

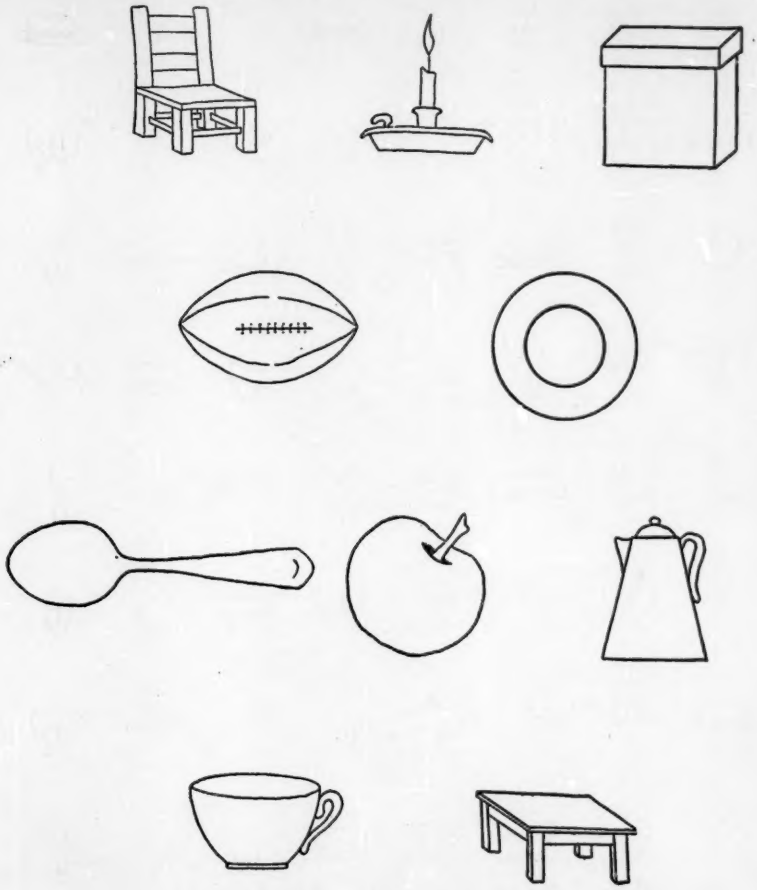


FIG. 7. PERCEPTION OF SPOON TEST—CARD 2

Motor Test: Drawing Straight Line Between Two Dots

The materials for this test consist of a pencil and 4 slips of paper about

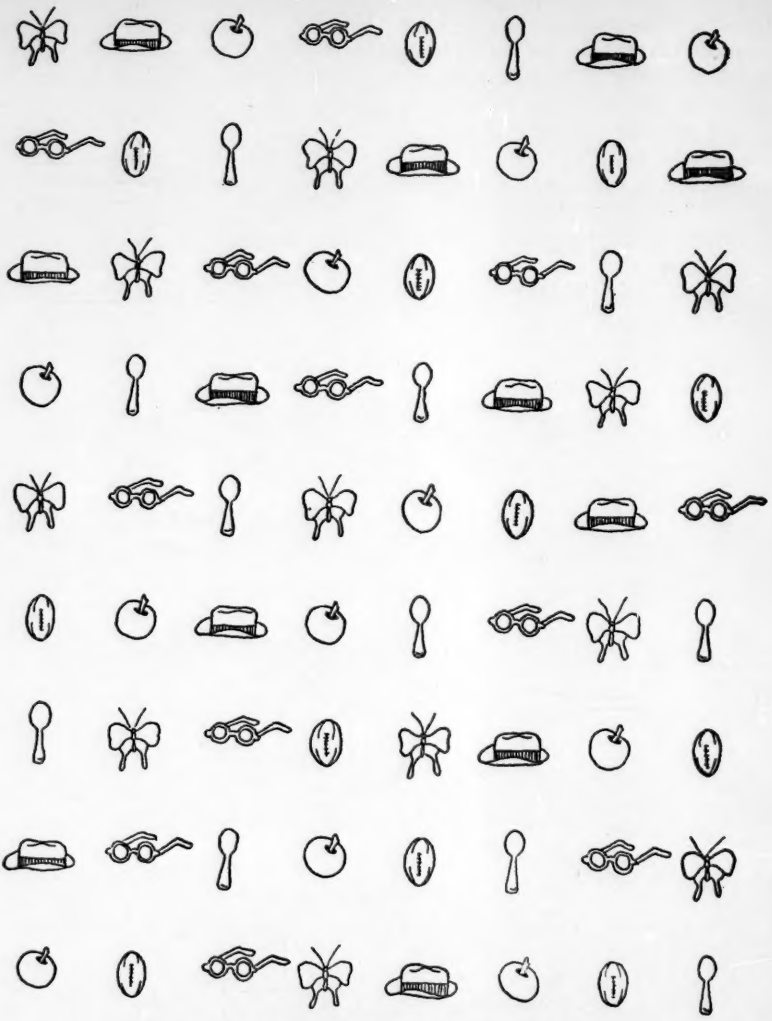


FIG. 8. PERCEPTION OF SPOON TEST—CARD 3

4½ by 5½ inches, on each of which are 2 dots 75 mm. apart. On the first and third slips, the dots lie in a line slanting 30 degrees to the left of the vertical and 60 degrees above the horizontal. On the second and fourth slips, the dots lie in a line slanting 30 degrees to the right of the vertical and 60 degrees above the horizontal.

The child is presented with a pencil

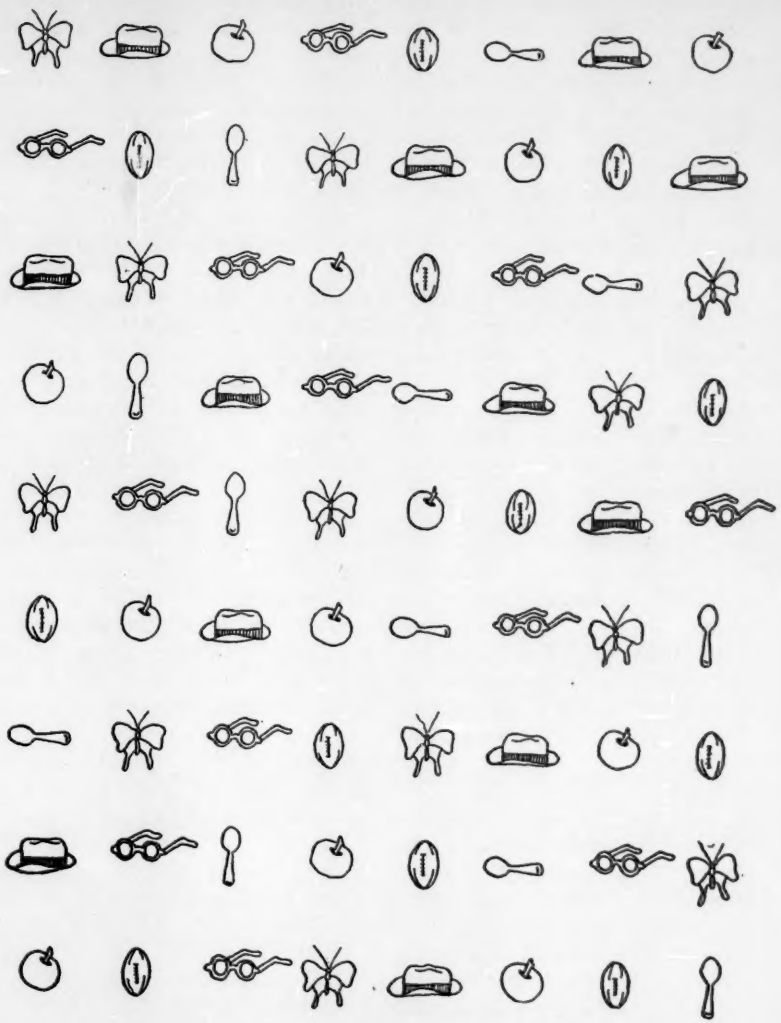


FIG. 9. PERCEPTION OF SPOON TEST—CARD 4

and the first slip with the directions: "See these two dots? I want you to see what a nice straight line you can draw me from this dot here (pointing to the dot nearest the child) to this dot here (pointing to the dot nearest the experimenter). Begin here (pointing again to the dot nearest the child)."

This last instruction checks a frequent tendency to begin drawing at the dot nearest the experimenter.

Time is taken from the moment the child begins to draw until he takes his pencil from the paper. An arrow is used to indicate the direction in which the line is drawn, and the paper is numbered 1, so that any failure to carry out directions may be checked in the analysis.

Three more slips of paper are given, numbered 2, 3, and 4 respectively, for which the directions, procedure, and record are the same except for the fact that the lines are to be drawn in different directions. On the second slip, with its 2 dots in a direction 30 degrees slant to the right of the vertical, and 60 degrees above the horizontal, the line is to be drawn from the one nearest the child to the one nearest the experimenter, as in the first slip. The third slip is like the first in form, and the fourth slip is like the second, but in both cases, the lines are to be drawn from the dot nearest the experimenter to the dot nearest the child.

SUBJECTS

The subjects for the experiment consisted of 226 children between the ages of two years, seven months and nine years, three months secured from the Child Institutes at the Johns Hopkins University and the University of Minnesota, and the kindergartens and first and second grades of two private schools in Baltimore, Maryland. A survey of occupational group and social class was unavailable, but in general the children came from homes of better class business and professional men. Mental ages were available for only 138 of the group, and so could not be used in the evaluation of the data. But the I. Q.'s for those for whom the figures were available ranged from 78 to 158, with 15 cases below 100, and 15 cases above 130, a median of 115.5 and a mode of 116.

The subjects may be first divided into 4 groups according to the type of data which could be collected for them. The standard group (S), of 132 children, is composed of those for whom a complete set of data is available, and for whom the second test period followed exactly two weeks after the first. For the delayed group (D) of 23 children, a complete set of data is available also, but for this group, the second test period was delayed anywhere from 1 to 10 days beyond the two week interval. The incomplete group (I) of 36 children presents data for the first test period only. Finally, a preliminary group (P) of 35 children presents data only for the first discriminatory perception test, and these data are in such form as to be comparable but not identical with the data furnished in this test by the other subjects. Though the procedure was the same, only 3 of the 4 cards were used, and the scoring, done on the basis of 3 responses, and any notes on the behavior of the child, allowed a considerable amount of error to enter into the score given.

In general the unit of age employed was six months. From table 1 it will be seen that the greatest concentration and most even distribution of cases fall in the age groups from four years to eight years, which period, under the conditions of the experiment contains

the critical point in the age scale. Below and above this period other factors enter to a large extent to confuse the data. The justification of the inclusion of these cases in certain uses of the material will be evident later.

TABLE 1

Age distributions according to subject groups

AGES	S	D	S+D	I	S+D+I	P	S+D+I+P
2:1–2:6	0	0	0	0	0	4	4
2:7–3:0	3	0	3	0	3	5	8
3:1–3:6	7	3	10	0	10	6	16
3:7–4:0	3	0	3	0	3	6	9
4:1–4:6	8	2	10	3	13	5	18
4:7–5:0	9	4	13	5	18	8	26
5:1–5:6	11	2	13	4	17	1	18
5:7–6:0	7	1	8	9	17	0	17
6:1–6:6	21	4	25	0	25	0	25
6:7–7:0	18	6	24	3	27	0	27
7:1–7:6	19	0	19	8	27	0	27
7:7–8:0	19	0	19	4	23	0	23
8:1 and above	7	1	8	0	8	0	8
Total...	132	23	155	36	191	35	226

TREATMENT OF DATA

With the material gathered and carefully recorded, the next step consists in devising methods of scoring by which it may be evaluated and compared.

The diamonds are scored according to their excellency of form. A score of 1 is given when no attempt to make a copy is evident,—the usual response of children too young to understand the problem. A curved line enclosing a space is given a score of 2 points, and a score of 3 follows a reproduction of certain distinct characteristics of the figure, such as straight line boundaries and angles. An inferior diamond with 4 sides and 4 angles and a semblance of symmetry is given a score of 4, while a score of 5 follows good proportion and correct orientation (fig. 10).

The child's score for the diamond copying experiment is determined from the scores for the 4 separate diamonds as follows: (*a*) If three or four of the 4 scores are the same, the summation score is taken as the same as the identical scores. (*b*) If the scores are divided 2 and 2, the higher number is taken as the summation score. (*c*) If 2 of the scores fall on 1 number, and the other scores are both odd, the summation score is considered as the mean, calculated to the nearest whole number. In every case under this category the estimated score falls on one of the numbers included in the individual scores. These scores, though rough, are comparable to the more or less rough scores of the other tests. Over two-thirds of the scores fall under category *a* above, and another scant fifth fall under *b*, so that in general these scores are quite representative of the ability of the subjects. A further use of the diamond copying scores is made by calculating a summation score for the scores obtained when the copying was done with the model in sight, and one for the scores obtained from memory.

On the perception tests a score of 0 is given for total failure on all 4 cards, a score of 1 if one form is discriminated, of 2 if two are discriminated, and of 3 if three are discriminated. A score of 4 is given for a correct discrimination of form regardless of its orientation on all 4 cards, and a score

of 5 is given for a correct discrimination of form on all 4 cards, with an indication of the difference in orientation on 1 of the last 2 cards. (It is interesting to note that in no case during the entire experiment was there a discrimination *against* the diamonds on card 4 which corresponded in position to the model.) Finally, a score of 6 is given for a correct discrimination of form on all 4 cards, with an indication of the difference in orientation on both of the last 2 cards.

To make these scores comparable for correlation to the 5 scores of the copying and motor tests respectively, the first 4 scores were grouped as 2. 0 and 1 were grouped together as scores in which chance was the determining factor of choice, and 2 and 3 were grouped together as scores in which perception of similarities between forms was just beginning to appear.

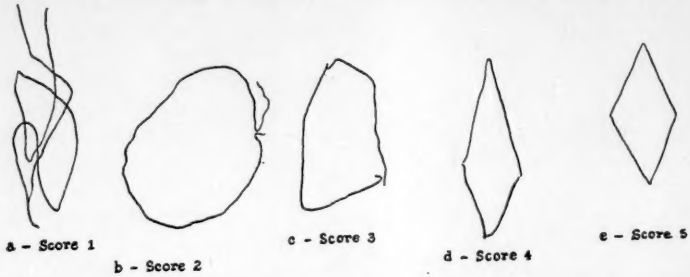


FIG. 10. SAMPLES OF SCORINGS FOR DIAMOND COPYING TEST

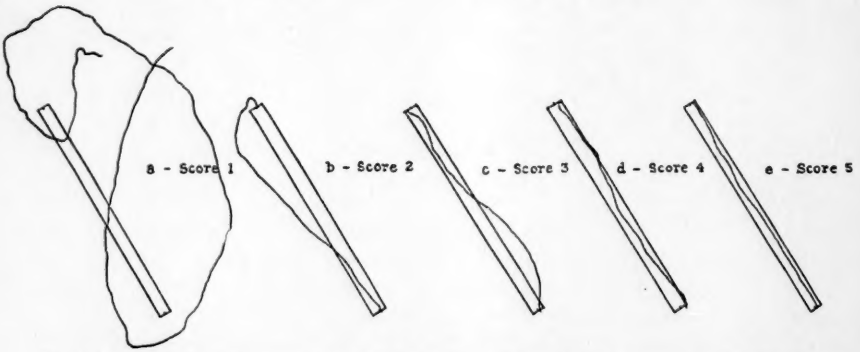


FIG. 11. SAMPLES OF SCORINGS FOR MOTOR TEST BY DETERMINING AMOUNT OF DISTANCE GOVERNED WITHIN 2 MM. RADIUS OF DIRECT PATH

In scoring the performances of the children on the motor test a scale was constructed from transparent celluloid which could be superimposed on the line drawn and so oriented that on it could be roughly measured the amount of deviation of the line from the direct

path between the 2 dots. Both the motor test and the method of marking it are modifications of the test used by Miss Wellman (23) at Iowa, in her study of the development of motor coördination in young children By this scale, it may be determined what percentage of the distance between the

TABLE 2

Frequencies of scores for perception of diamonds

AGES	SCORES							TOTAL
	0	1	2	3	4	5	6	
2:1–2:6	4							4
2:7–3:0	5		2			1		8
3:1–3:6	4	3		2	5	2		16
3:7–4:0			2		5	2		9
4:1–4:6		2	2	1	12	1		18
4:7–5:0	1		1	2	17	2	3	26
5:1–5:6				1	10	1	6	18
5:7–6:0				1	10	3	3	17
6:1–6:6					9	3	13	25
6:7–7:0					8	4	15	27
7:1–7:6					1	3	23	27
7:7–8:0				1	1	5	16	23
8:1 and above					3	1	4	8
S + D + I + P								226

TABLE 3

Frequencies of scores for perception of spoons

AGES	SCORES							TOTAL
	0	1	2	3	4	5	6	
2:1–2:6								0
2:7–3:0	1			1	1			3
3:1–3:6	2				8			10
3:7–4:0					3			3
4:1–4:6					10			10
4:7–5:0					10		3	13
5:1–5:6					7		6	13
5:7–6:0					4		4	8
6:1–6:6					5	3	17	25
6:7–7:0					4	2	18	24
7:1–7:6					2	1	16	19
7:7–8:0					1	1	17	19
8:1 and above					1	1	6	8
S + D								155

TABLE 4

Frequencies of scores for drawing of diamonds —Combined scores for drawings from model, and drawings from memory

AGES	SCORES					TOTAL
	1	2	3	4	5	
2:7–3:0	3					3
3:1–3:6	2	7	1			10
3:7–4:0		2	1			3
4:1–4:6	1	2	7			10
4:7–5:0		3	10			13
5:1–5:6		2	7	4		13
5:7–6:0				8		8
6:1–6:6			10	13	2	25
6:7–7:0			1	21	2	24
7:1–7:6			2	13	4	19
7:7–8:0			2	14	3	19
8:1 and above			2	4	2	8
S + D						155

TABLE 5

Frequencies of scores for motor test

AGES	SCORES					TOTAL
	1	2	3	4	5	
2:7–3:0	1	2				3
3:1–3:6	2	6	1	1		10
3:7–4:0			2	1		3
4:1–4:6	2		4	4		10
4:7–5:0			7	6		13
5:1–5:6			5	8		13
5:7–6:0			1	7		8
6:1–6:6		1	9	12	3	25
6:7–7:0			10	13	1	24
7:1–7:6			4	14	1	19
7:7–8:0			6	10	3	19
8:1 and above			1	6	1	8
S + D						155

2 dots is covered within 2 mm. deviation from the direct course. A series of 5 scores is used. A score of 1 is given to a performance in which there is no attempt to fulfill the terms of the problem. A score of 2 is given to a performance in which less than 33 per cent of the distance is covered within the 2 mm. radius. A score of 3 is given to a performance in which between 33 and 67 per cent of the distance is covered within the 2 mm. radius, and a score of 4 is given to a performance in which between 67 and 100 per cent of the distance is covered within the 2 mm. radius. Finally, a score of 5 is given to a performance in which 100 per cent of the distance is covered within the 2 mm. radius (fig. 11). In determining a score for a particular child, the per cents for each of the 4 lines are added and the final score is calculated on the basis of one-fourth of the summation values thus obtained.

TABLE 6

Averages and ranges of time in seconds for responses in perception experiments

	DIAMOND TEST			SPOON TEST		
	Number	Average	Range	Number	Average	Range
Total	620	6.1	.2–45.0	620	4.6	.2–45.0
Correct	586	6.1	.2–45.0	607	4.7	.2–45.0
Incorrect	34	6.3	.4–44.0	13	2.2	1.0– 5.6
Card I:						
Total	155	1.8	.2–44.0	155	.9	.2– 7.0
Correct	149	1.4	.2–10.8	151	.9	.2– 7.0
Incorrect	6	10.1	.4–44.0	4	3.1	1.4– 5.6
Card II:						
Total	155	2.5	.4–20.2	155	1.0	.2– 7.2
Correct	143	2.3	.4–20.2	152	1.0	.2– 7.2
Incorrect	12	4.7	1.0–18.4	3	2.5	1.0– 5.0
Card III:						
Total	155	17.3	1.2–45.0	155	14.2	.8–45.0
Correct	147	17.9	1.2–45.0	152	14.2	.8–45.0
Incorrect	8	7.4	1.2–28.2	3	1.5	1.0– 2.0
Cor.—Orient. absent	80	6.2	1.2–40.4	63	4.5	.8–25.4
Cor.—Orient. present	67	31.8	4.4–45.0	89	21.5	1.0–45.0
Card IV:						
Total	155	2.9	.4–24.0	155	2.3	.4–28.0
Correct	147	2.8	.4–24.0	152	2.3	.4–28.0
Incorrect	8	4.7	2.6–14.0	3	1.7	1.0– 2.0
Cor.—Orient. absent	63	3.1	.4–24.0	60	2.4	.6–28.0
Cor.—Orient. present	84	2.6	.4– 8.9	92	2.2	.4–15.4

Such methods of scoring are rough, but the lack of standardization of the tests themselves would obviate finer treatment, and each test, as scored, indicates within itself, a consistent advance in performance ability from year to year (see tables 2, 3, 4, 5).

Experimentation in the handling of the data so as to give an accurate picture of what actually took place, demonstrated that, due to certain gaps in the data at the present time, a treatment of the data as actual frequencies rather than as per cents was much less confusing. For this reason, except in a few special cases which will be clearly stated, the actual frequencies are used as the working figures throughout the treatment of the data.

Time and correctness of response in the perception experiments

A tabulation of the time averages and ranges is given in table 6 for both the perception experiments. From this, the following facts are evident: (1) In all the responses exclusive of those to the third and fourth cards in which orientation is differentiated there is a gradual increase in time required for the response from card to card for the first 3 cards, due to the increased complexity of the task. This is not true for the fourth card which is enough like the third to make the effects of learning evident in the response. (2) The responses for the second experiment are shorter than those for the first, again probably showing the effects of learning. (3) The incorrect responses are longer for the same cards than the correct, with a few exceptions due to the low number of incorrect cases as compared with the correct. (4) Finally, the extreme increase in the reaction times for card 3 is apparently due to the weighting given by the responses in which orientation is differentiated. Such responses are lengthened by the fineness of the differentiation required, and are frequently accompanied by hesitations and comments which show a recognition of the reversed position of the figure, and which indicate that the response is to 2 similar figures in different positions, rather than to 2 different figures. After the third reaction, the reaction to the fourth card becomes a relatively simple matter, as is indicated by the very much lower time average for this card than for the third. The third card, then requires the solution of a problem by the child, and the way the problem is solved seems to throw a good deal of light on the stage of development the perceptual life of the child has reached at the time of the experiment.

The factor of orientation as treated by the first perception experiment

The point of primary interest in the experiment is the analysis of the distribution of scores in the discriminatory perception tests, and of the bearing of the results on the question of orientation of figures as a factor in their perception. For this analysis, the material in the S, D, I, and P groups is used, for though the data in the last group have been collected under slightly different conditions, the age range of the group is such that, if its inclusion is justifiable at all, it will serve to add materially to the clearness of the frequency curves. It is felt that its inclusion is justifiable, moreover, because of the very slight change which occurs in the form of the frequency curves when these data are added. A study of the probabilities of curve fit showed that only in 1 age group does the figure drop below

.8, and in this particular case, the accumulated frequency of the S, D, and I groups is increased 200 per cent by the addition of the P data. Considering the small number of cases included, the probabilities are great enough to justify the addition of the data in the P group to those of the other three groups.

The curves of this distribution of score frequencies plotted from the data of table 2 are shown in figures 12 and 13. In figure 12, which shows the other than the diamond. With one exception these occur below the age level of 3 years 4 months. The score of 1 has 4 possible forms. Of these, 3 occur, and within the 5 cases, 3 of the correct responses fall on the first card, and 1 each on the second and third. It is somewhat doubtful whether such responses indicate anything more than chance successes. The predominance of successes on the first card may indicate that the perceptual ability is there but that the child has not yet

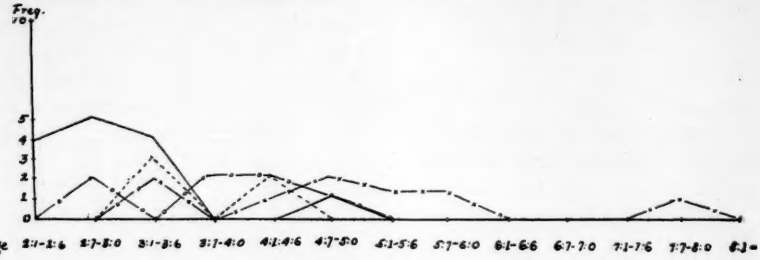


FIG. 12. SCORE FREQUENCIES FOR AGES—FIRST PERCEPTION TEST—SCORES 0, 1, 2, 3—S + D + I + P

——— = 0 score.
---------- = 1 score.
—o—o— = 2 score.
—x—x— = 3 score.

curves for scores 0 to 3 inclusive, in spite of the still too scanty number of cases, the general tendency for each succeeding score to persist to a greater age than the one just below it is evident, showing a gradual development of perception from a stage of no recognition to one of fairly accurate discrimination. A closer inspection of the various kinds of responses for which these scores stand is interesting in this connection. The 0 scores, obviously, are those in which all 4 responses (3 in the case of the P data) are to figures developed a sufficient degree of concentration to carry the problem in mind without distraction through the 4 responses. At least it rather obviates the possibility that the main cause for error is a lack of understanding by the subject of the problem in hand. The elements of chance success and lack of concentration seem to carry over into the 2 score. Here, in the total of 7 cases, 3 made correct responses to the first and third cards, 2 to the first and second cards and 1 each to the second and third and to the third and

fourth cards. For the score of 3 less variation is shown than would seem probable. Six of the 8 cases indicate correct responses for the first, third and fourth cards, and the other two for the second, third and fourth cards. The predominance of errors on the second card, and the form those errors take indicates that the low score is a lack of appreciation of the problem to which the response is to be made.

A further analysis of the types of errors made in scores 0, 1, and 2 indicates an interesting course of development in discrimination. Of the 46 possible responses included in the 0 scores, 1 response was wholly negative, 10 consisted in pointing to each figure

FIG. 13. SCORE FREQUENCIES FOR AGES—FIRST PERCEPTION TEST—SCORES 4, 5, 6—S + D + I + P

——— = 4 score.
---------- = 5 score.
—o—o— = 6 score.

caused mainly by the fact that the child has not yet reached the age of critical discrimination of form. Four of the 6 errors on the second card consist in responses to triangles, and the other 2 in responses to a truncated triangle and a rectangle respectively—all forms very similar to the diamond. The 2 errors on the first card consist in responses to the circles, and may indicate on the card in turn, 27 consisted in pointing to a circular figure (the circle on the first 2 cards and either the elipse or the wheel on the last), 3 to a rectangle, and one each to a curved-topped quadrilateral, a star, a hexagon, a pyramid of three bricks, and an irregular quadrilateral. The great predominance of responses to the circular figures is interesting in connection with

the general contention that circles are the first recognizable drawings made by children, and probably the first plane figures recognized by them. The response of pointing to each figure on the card in turn is also indicative of a very early stage of the response and does not occur except in the 0 score group. Among the cases scoring 1 point the responses to circular figures still appear as the most frequent errors, and comprise 4 of the 13 possible responses. After this, stars and rectangles occur twice each, and there are single responses each to the triangle, curved-topped quadrilateral, irregular quadrilateral, pyramid of bricks and bow. Here we find an increase in the proportion of angular figures. Whether or not we can say that the child is choosing them because they are more like the diamond is doubtful. But at least we are approaching a broader field of recognition than that limited to the circular forms. This field broadens still farther in the cases in which 2 correct responses are given. Here, of the 9 instances of error only 3 are circular figures, while 2 are triangles, and single cases occur of the rectangle, curved-topped quadrilateral, pyramid of bricks, and bow. Though there is here a lack of any particular emphasis on the circular figures, the figures chosen, as a whole, do not yet bear any striking resemblance to the diamond, as is true in the errors recorded in connection with the scores of 3.

With this picture of the general perceptual development as a background, it is most interesting next to compare the curves for the next 4 scores, all of which stand for perfect discrimination of the diamond, but with different qualitative factors included. In figure 13, which shows the curves for scores 4 to 6 inclusive, an exceedingly interesting period of development is displayed. Appearing as early as three years in a few scattering cases and rising rapidly to a climax between four and one-half and five years, the recognition of likeness between the 2 figures, regardless of their orientation on the sheet—as represented by a score of 4—begins to drop off in the face of the rising scores 5 and 6. Indeed, scores 4 and 6 show a very beautiful opposition representative of the antagonism of the 2 responses implied. For the recognition of likeness between 2 figures only when they are identically oriented—as represented by the score of 6—not only develops after the state represented by 4, but develops to its final exclusion. Score 5, on the other hand, representing an apparent state of doubt on the part of the child between scores 4 and 6, shows no peak between the peaks of these scores—a situation which might have been expected rather than the one shown. In fact, the distribution of score 5 as it appears in the curves raises a strong question whether the jump from a score of 4 to a score of 6 is not a sudden one, with no intermediate step, and whether the score here represented by 5 may not represent an even greater mental development than that represented by 6. On the face of it the drop of the curve of score 6 from a frequency of 23 at seven to seven and one-half years to a frequency of 16 at seven and one-half to eight years, and a coincident rise of score 5 from 3 to 5 during the same

time may be significant. Beyond eight years, the forms of the curves are not significant—a fact which was previously stated in the discussion of the choice of subjects. Whether the addition of more subjects in age ranges above these studied here would lead to a further drop in the curve of score 6 and a corresponding rise in the curve of score 5 will need further experimentation to determine. If, as Dunlap has stated, in developing perception we are at the same time developing thinking by laying in store elements later to be used in thinking, might not the state represented by score 5 be one in which a more comprehensive integration of perceptual elements had been utilized, i.e., a state in which simplicity of response had given place to a complexity of possible responses which made the final choice doubtful, hesitating, and perhaps we might say, more thoughtful than the rest. A closer analysis of the actual responses grouped under the score of 5 may throw some light on the matter.

The absence of card 4 from the P group obviates the use of these data in such an analysis, but among the total number of 191 cases included in groups S, D, and I, 24 received a score of 5 on the first perception experiment. Three of these 24 cases were instances in which the child responded to the third card negatively, in one case being unable to find a figure like the model until the model had been turned into the position of the diamonds on the card, and in the other 2, pointing to some of the diamonds on the card, but objecting to the fact that they were turned in the wrong direction. At the presentation of the fourth card, however, both positions of the diamond were pointed to without discrimination in all three cases. In the 2 cases which commented on the difference in orientation, each child seemed perfectly conscious of the factor, but seemed to be having difficulty in deciding whether the experimenter wanted the diamonds pointed out with reference to or in spite of it, and finally decided to do it in spite of the factor. The other case showed nothing by which such an interpretation could be made.

In the other 21 cases, the situation was reversed. Here the diamond on card 3 was pointed to with little or no hesitation and without any apparent consideration of orientation as a limiting factor. But upon the presentation of the fourth card on which diamonds appeared in both positions only those in the same position as the model were indicated. In no case was there any attempt on the part of the child at an explanation of what to an adult mind would be an ambiguous response. The child was apparently solving each situation as it came up. Either the lack of any diamonds on the first card to correspond exactly with the model led to the choice of the second best, and the presence of both kinds on the fourth card led to the choice of only those most exactly like the model, or else the presence of the 2 kinds on the fourth card called the child's attention to a factor which he had not noticed before, and served as a suggestion to him to treat the situation in a new way. If the latter is the case it may well be argued that the reaction receiving a score of 5 is a mere intermediate response between the reac-

tions represented by scores 4 and 6. If the former is the case the reaction would seem to be more that of indecision on the part of the child as to just what sort of a reaction is wanted. There is nothing within the experiment itself by which the possible attitude of the child can be discovered, or by which we are justified in assuming one explanation or the other for the occurrence of a reaction corresponding to score 5.

A tabulated comparison of the responses to cards 3 and 4 for all the 191 cases in groups S, D, and I show that 88 per cent of the responses are in agreement on the 2 cards, while only 2 per cent (those receiving score 5) are in disagreement. Of the 88 per cent in agreement, 5 per cent (including all individuals having scores of 0, 1, and 2) were consistently incorrect, 41 per cent (including all individuals having scores of 3 and 4) were consistently correct, but showed no sign of the recognition of differences in orientation, and 43 per cent (including all individuals having a score of 6) were consistently correct and cognizant of orientation as a factor in the perception of likeness in plane figures. The relatively small number of inconsistent responses would lead one to one of two conclusions, either that the stage of uncertainty, if existing, as was first thought, between types of responses represented by scores 4 and 6, is extremely transient, and is caught only very infrequently by such a test, or the inconsistent response is a more mature response than those represented by either score 4 or score 6, and so is only beginning to appear in the age range here covered. Careful developmental study of a considerable number of individual children over a number of years would indicate any bases for accepting or discarding the first conclusion, while an extension of the upper age limit on the present experiment would go far in justifying or eliminating the second. The status of the scoring in this experiment is as yet so much that of uncertainty that it is impossible to state arbitrarily, without this further study, that one of these three higher scores indicates a more mature response than another. We can merely point to the results of the experiment as indicative of a fairly clear state of affairs during the ages two and one-half to eight years, and leave the significance of the various responses, in the light of maturity of development to be determined after further experimentation at other age levels.

A comparison of the first and second perception experiments with a view to the part familiarity of the figure may play in the modification of the reaction to orientation

A comparison of the first and second perception experiments involves only the data from subject groups S and D. The justification of the use of the D data in the second perception test (which might be questioned because of the variability of the time between the 2 test periods for this group) is based on a comparison of the closeness of fit between the frequency curves for the 2 groups on the first test, and the closeness of fit between the curves for the 2 groups on the second test. In only one case does the difference between the closeness

of fit in the first experiment and the closeness of fit in the second exceed twice the value of sigma and become significant, and that particular instance is one in which the discrepancy lies obviously in the low value of the probability in the first perception experiment.

In proceeding, then, to a comparison of the results obtained on the first perception test with those obtained on the second test, for the S and D groups —155 cases in all, it was assumed at the outset that the factor of familiarity of the figures might in some way affect the influence of the factor of orientation, and that if this influence were present, it would probably be on the side of lessening or even eliminating the effect of orientation, so that the child would pay no attention to the position of the figure in his choice. Here ease of recognition would increase the likelihood that slight differences of detail would be overlooked. A general correlation between the scores on the two tests irrespective of age gives .66±.032. This correlation, in the absence of other tests of the same factor to which this test may be compared, shows a good reliability of the test within itself. It also seems to indicate that though there may be some factor entering in the second test which was not present in the first, to keep the correlation from being higher, whatever that factor is, it does not have any tremendous effect one way or the other. A close analysis of the changes in score from one test to the other will be interesting in this connection. If the factor is the one of familiarity mentioned above, one would expect to find a good majority of losses in score over gains, especially among the scores 4, 5, and 6. As a matter of fact, in the 45 cases in which a change in score occurs between the first experiment and the second, there are 36 cases in which the score is raised and only 9 cases in which the score is lowered. Each of these 9 cases, moreover, represents only a single point's loss, one being a drop from a score of 1 to a score of 0, 7 being drops from scores of 5 to scores of 4, and 1 being a drop from a score of 6 to a score of 5. The gains, on the other hand, not only predominate four to one in number, but range in magnitude from one to four points and total 62 of the 71 total points of change recorded between the 2 experiments. A detailed table of the gains and losses will be found in table 7. It is fairly certain from this that familiarity with the figure, if it does serve as a limiting factor, does not tend to overshadow the factor of orientation. If anything, it tends to sharpen it, though

TABLE 7

Detailed table of gains and losses in score for whole group,—from diamond perception test to spoon perception test

LOSSES				GAINS			
Score		Frequency	Per cent of total	Score		Frequency	Per cent of total
From	To			From	To		
1	0	1	11	0	3	1	03
5	4	7	78	0	4	2	05½
6	5	1	11	1	4	2	05½
				2	4	1	03
				3	4	5	14
				3	6	1	03
				4	5	3	08
				4	6	11	30
				5	6	10	28

the tendency to increase in score is probably not sufficient to warrant the assumption of any factor other than the mere greater familiarity with the procedure which the child experiences at the second test period.

The probability that greater familiarity with the procedure of the second test is the determining factor in changes in score between the two tests is heightened by an inspection of table 9. From this it is evident that 28 of the 45 changes—both gains and losses—are from one of the doubtful scores, 0, 1, 2, 3, or 5 to one of the positive scores, 4 and 6, and 11 of the gains are from score 4 to score 6, i.e., from one positive score to another more advanced. Thirty-nine, then, of the 45 changes are toward greater certainty. Two, one loss in score from 1 to 0, and one gain in score from 0 to 3, are from hesitation to hesitation in nature, and only 4, one loss in score from 6 to 5, and three gains in score from 4 to 5 show a change from positiveness to hesitation. In general, then, on the second test the children were much surer of what they were going to do, and probably the correlation between the 2 tests is as low as it is, merely because of the greater familiarity of the children with the experimental procedure at the second test period, and not because of the interference of a factor of familiarity of the figure with the factor of orientation. This point could be assured by reversal of the order in which the 2 perception tests are presented to the children.

A further analysis of the distribution of the changes in score shows that they are fairly evenly distributed over the age range. Twenty cases of change occur in the first 3 years of the age scale, from two years seven months to five years six months, and 25 cases occur in the last 3½ years, from five years seven months to nine years three months. Of the 20 cases of change in the first half, 15 are cases of gain and 5 are cases of loss, while of the 25 cases of change in the second half, 21 are cases of gain and 4 are cases of loss. Among the gains, those of the greatest magnitude are confined to the earlier 3 years. In this group are 100 per cent of the gains of 4 points and 3 points, 25 per cent of the gains of 2 points and 33 per cent of the gains of 1 point, and the other 75 per cent of the gains of 2 points and 67 per cent of the gains of 1 point comprise the total number of gains in the last three and one-half years.

Generally speaking, though the gains and losses are fairly well distributed over the age scale, the gains for the first three years average much larger than those for the last three and one-half years. This fact in itself would tend to lower the correlation between the 2 tests, and further emphasizes the fact that it is probably the greater familiarity with the procedure of the second test which accounts for any differences between the 2 performances.

Comparison of the tests of discriminative perception with the related tests of copying and motor control

It remains now to show what bearing performance on these tests of discriminative perception has on the ability of a child to copy a given figure, and to compare the relative

parts perception and motor ability play in such copying. For this only S and D data are used.

Because of incomparable scaling of the perception tests as compared with the better standardized scores on the other two tests correlations are of little significance except to indicate the possible validity of the scoring of the perception tests themselves. A better comparative picture of the responses given on the respective tests is gained from tables 8, 9, 10, 11 and 12.

While the table giving the scores of the diamond copying test as compared with the motor test scores shows an even progression between the 2 tests, the tables giving the score

TABLE 8

Frequencies of scores for perception of diamonds as compared with scores for copying diamonds

PERCEPTION OF DIAMOND —SCORES	DIAMOND COPYING TEST—SCORES				
	1	2	3	4	5
6			13	45	8
5		1	5	9	5
4	1	9	21	22	1
3		3	3		
2		1	1		
1	2	1			
0	3	1			

TABLE 9

Frequencies of scores for perception of spoons as compared with scores for copying diamonds

PERCEPTION OF SPOON— SCORES	DIAMOND COPYING TEST—SCORES				
	1	2	3	4	5
6			18	56	12
5			1	6	
4	4	12	26	15	1
3	1				
2					
1					
0	1	2			

TABLE 10

Frequencies of scores for perception of diamonds as compared with scores for motor test

PERCEPTION OF DIAMOND —SCORES	MOTOR TEST—SCORES				
	1	2	3	4	5
6			19	42	5
5	1		7	11	1
4		3	23	26	2
3		1	1	4	
2	1	1			
1	2	1			
0	1	3			

TABLE 11

Frequencies of scores for perception of spoons as compared with scores for motor test

PERCEPTION OF SPOON— SCORES	MOTOR TEST—SCORES				
	1	2	3	4	5
6			28	53	6
5			3	3	1
4	4	6	19	27	1
3		1			
2					
1					
0	1	2			

TABLE 12

Frequencies of scores for diamond copying test as compared with scores for motor test

MOTOR TEST— SCORES	DIAMOND COPYING TEST—SCORES				
	1	2	3	4	5
5			2	5	1
4		5	20	47	11
3		5	19	25	1
2	4	4	1		
1	2	2	1		

frequencies for the perception tests and the others show the difficulty which arises in trying to get an even progression between two tests graded in such a manner that one presents a unimodal curve of frequency and the other a bimodal, and that while one is scaled high enough so that there is a drop in frequency at the end of the curve, the other is not. In spite of this, however, there is indicated a more or less parallel progression of the two sets of scores in each case. This is more true of the tables comparing the scores of the first perception experiment with the other tests than of those comparing the second perception experiment with the same tests—a fact which bears out still further the contention of a difference between the factors involved in the two perception tests.

TABLE 13

PERCEPTION OF	DRAWINGS OF	r	PEr	Pr
Diamonds	All diamonds	.35	.032	.0000006
Spoons	All diamonds	.01	.05	.865
Diamonds	Diamond from model	.37	.047	.00000022
Spoons	Diamond from model	.16	.05	.0424
Diamonds	Diamond from memory	.46	.05	Negligible
Spoons	Diamond from memory	.25	.05	.000938

TABLE 14

FACTORS INVOLVED		r	PEr	Pr
All diamonds	Motor Test	.18	.05	.0208
Memory diamond	Motor Test	.25	.05	.000938
Visible diamond	Motor Test	.25	.05	.000938

The correlations serve to show some interesting tendencies (see table 13). The first thing of note in these figures is the lowness of the correlations between the second perception experiment and the diamond tests in comparison with the substantial correlations between the first perception experiment and the diamond tests. This phenomenon is explainable first on the grounds that the first perception experiment and the diamond tests were done on the same day, while the second perception test was performed two weeks later, and second, by the factors of learning and greater familiarity with the procedure epxerienced in the second test period. The scores on the first perception test are undoubtedly a more accurate estimate of the general state of the child's perceptive ability along the lines indicated than scores on the second perception test, and for this reason the fairly high correlations between this test and the diamond test are of vast interest in indicating a parallel development of perception and ability to copy figures.

The second point of interest in the above figures lies in the fact that the highest correlation is between the perception of diamonds and the dia-

mond drawn from memory. The factor of holding a memory image of the figure long enough either to find it again or to reproduce it seems to bind these 2 tests together. The correlation between the memory diamond scores and the visible diamond scores is .36 ±.047, and the fact that the correlations between the first perception test and the diamond copying test are as high as or higher than this correlation is an added point in favor of conceding some slight significance to the figures.

The correlations between the scores for the diamond copying tests and the scores for the motor tests are shown in table 14. They are positive, but less significant, a fact doubly interesting because these correlations are between 2 relatively well standardized tests.

Finally, the correlation between the scores on the motor test and the scores on the first perception test is found to be .68 ±.03. This is the highest correlation to be found in the whole group, and is interesting in view of the axiom derived from the response hypothesis that accuracy of motor response is a basis for accuracy of perception and later of thought. It may be that precocity in general motor development is paralleled by a corresponding precocity in the development of perception, and that the reason the correlation between the motor test and the diamond drawing tests is not greater lies in the greater complexity of the factors involved in the diamond drawing tests which are as yet unanalyzed and confuse the issue.

The probability of entrance of extraneous factors into the second perception test is strikingly substantiated, in the view of the last paragraph by the fact that the correlation between this test and the motor test is −.17 ± .05.

To return to the nature of the response scored as 5 on the perception experiments in the light of this discussion—if score 5 is in reality a superior score to score 6, we would expect to find that the motor scores for children receiving scores of 5 on the first perception experiment would be relatively higher than those for the other children. But, in 10 of the 20 cases in which these data are available, the scores on the motor test fall exactly on the modes of the score frequency curves for the particular ages, in 7 cases they fall 1 point below the mode, and in 3 cases they fall 1 point above. Very little conclusive evidence is to be obtained from this survey, and what may be obtained rather disavows any superiority in the children scoring 5 on the first perception test.

CONCLUSIONS

Summarizing, it must be said that the results are on the whole indicative rather than conclusive. The subjects are too few, and there is too little material with which to compare the results of the tests, to give the interpretations herein presented other than a tentative aspect. A few points, however, are clearly brought out as follows:

1. Orientation on the page, of plane figures, appears to rise rather suddenly as a factor in their perception between the ages of 5 and 6 years—or between the standard kindergarten age and the

standard first grade age. The break is apparently rather sudden for the individual child with little or no transition; and for the group, it may be located much more exactly than one might expect.

2. In the work here outlined, the degree of familiarity with the figures used in the perception tests seems to bear little or no relation to the reaction toward the orientation of the figures on the part of the child. Any relation which may exist, is in this case obscured by the effect of greater familiarity with the test procedure at the second test period.

3. The first perception test may be taken as a truer measure of the child's general perceptual development along the lines indicated than the second perception test, because of its greater freedom from any factor approaching that of learning.

4. Perceptual development appears to be more closely allied than motor development with development in imitative drawing.

5. A very high correlation exists between scores on perception and scores on motor control. Just what this means is speculative, but it is highly probable that it is indicative of a very close interplay of the two factors in the course of the development of the child.

6. Aside from these general points, a specific field for further speculation and investigation lies in determining the significance of ambiguous performances and in determining the relation of the responses given at these ages with those of adults.

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An Adaptation of the Ishihara Color Test for Use with Children of Pre-School Age

FLORENCE C. WOELFEL

IN THE absence of objective data, the usual viewpoint as to color vision and color discrimination in the pre-school child has been similar to that expressed by Spindler (3):

> "It seems certain that the perfectly normal child for some time after birth is color blind. The probability is that there is no accurate discrimination of colors felt by the child till he is three or four years old, and that the discrimination is exceedingly imperfect and proceeds very slowly and requires much time and training."

Sulina (4) reported an attempt to study in a fairly comprehensive way the development of color sense in children. He tested 336 children from one to fourteen years of age and concluded that the color sense is not developed under two years (15 cases), but that it begins to function and can be demonstrated at two years (29 cases), becoming completely developed between the fourth and sixth year (53 cases).

This article reports an attempt to adapt the Ishihara tests for color blindness for use with children approximately four to six years of age. If color sense is developing gradually toward perfection during this period, it would be interesting to have an easily applicable test which would show how far any individual child's color discrimination had proceeded.

For use with children of three to six years of age a matching test on a multiple choice basis was devised, the idea being that children of this age could show by matching the correct number with each of the Ishihara plates whether or not they could see the numbers on them as an adult of normal color vision would.

The Ishihara tests (2) consist of 16 plates, of which numbers I through XIII only were considered suitable for this adaptation. Each of the Ishihara plates shows a number made up of small dots of color on a continuous background of other similar dots of different hues. Each plate is so constructed that people of normal color vision can easily read the number correctly, while the color blind will read it as a different number (e.g. 3 instead of 8 for Plate II) or will be unable to read it at all. Two of the plates (X and XI) are so devised that the majority of the red-green blind will read a figure in each, while the majority of the normal (and the totally color blind) cannot see any number there, or can hardly read it. Thus the difference between the normal and the ab-

normal individuals in color vision is shown by the way they read the Ishihara plates.

A preliminary test of each child was necessary to show whether he could match numbers when the element of color was not involved. For this purpose a series of numbers was painted (black on a white background) on tracings of each of the numbers on the Ishihara plates, so that the black numbers would be of the same size,

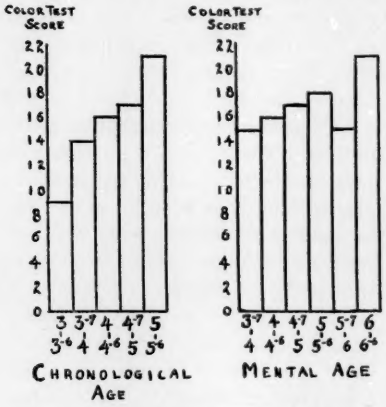

FIG. 1. MEDIAN SCORES FOR EACH AGE LEVEL

and similarly constructed of a series of dots rather than a continuous line. In the preliminary test each child was shown 4 at a time of these black numbers. The number to be matched was then placed just below the 4 and the instruction given to "find another one up there (pointing to the row of 4) just *like* this one: another one that is just the *same* as this one." The time required to match the number was taken by a stop-watch. In this preliminary test, if the child indicated a wrong number, the two were placed side by side and the question asked, "Are they the same"?, while the number was traced with the forefinger. In practically every case, the child then quickly made the correct choice, and very rarely was there more than one mistake of this kind in matching the series of black numbers.

For the color test proper, a series of numbers was made with water colors, duplicating as nearly as possible all the numbers on the Ishihara plates as they would be read by those of normal and of defective color vision. From these a multiple choice series of 4 numbers was selected for presentation with each plate, the series consisting of the correct number to be chosen by the normal, the number which a color blind person would be expected to see and two other numbers different in form and color from the two just mentioned. The position in the series of the correct and color blind choices was changed for each plate, so that choice would not be made on basis of position in the row. In giving the test, the Ishihara plate was placed below the row of 4 numbers and the child told, as in the preliminary test, "Find another one up there *just like* or just the same as this one." The time of each choice was also recorded, and any relevant remarks by the child or anything unusual in his manner of attacking the task were also noted. The series as presented for multiple choice with each Ishihara plate is given in table 1 with the normal and color defective scoring as given in the Ishihara booklet.

The Ishihara instructions say that 'it is essential that the test should be conducted in a light room in the day-

time.' In this experiment with children, the tests were given only on sunny days and the child was seated near a window, though the sunlight did not fall directly on the cards. Even on sunny days, however, the illumination is far from constant, as it varies with the time of the year and with the frequency of clouds which may now and then pass across the sun. In the interests of eliminating variability in illumination, it would undoubtedly have been preferable to give all the tests under standard artificial illumination, such as the Nela Daylight Screen.

TABLE 1

ISHIHARA PLATE NUMBER	MULTIPLE CHOICE NUMBERS	SCORING	
		Normal	Color Blind
I	5–12–7–6	12	12
II	3–5–8–2	8	3
III	2–5–7–6	6	5
IV	5–6–8–2	5	2
V	21–5–74–42	74	21
VI	6–5–2–8	2	†
VII	2–8–5–6	6	†
VIII	5–8–26–2	5	†
IX	6–7–2–8	7	†
X	8–6–5–74	*	5
XI	6–74–8–2	*	2
XII	6–74–26–2	26	Red blind 6 Green blind 2
XIII	4–74–2–42	42	Red blind 2 Green blind 4

* Majority can hardly read it.
† Can hardly read it.

One other minor point in technique is that of presenting the cards rapidly enough to sustain the interest and attention of children of this age level. Giving the whole test takes from twelve to fifteen minutes, not a long time, but there is little variety and not much inherent interest in the material for the pre-school child.

Mechanically the presentation is facilitated by having the multiple choice cards in a box similar to a small file with identifying tabs on each card, so that the four for each series can be quickly selected. It is also necessary to return each card to its place in the file after each choice, as most of the cards are used several times. This selection and return to the file becomes smoother and speedier with practice, so that the examiner can converse with the child between choices if advisable, and the child is less likely to be distracted by the mechanics of the process. These details of construction of the test and of technique in presentation have been given in order to make possible more valid comparisons in case anyone is in a position to try out the test further.

The subjects were nearly all from a nursery school and ranged from three years, one month to five years, five months of age. In addition, 8 children from a public school kindergarten were tested ranging four years, four months to five years, eight months. It is possible that the nursery school children, who had been frequently subjects for various psychological tests, may have been trained thereby to take a better test attitude. It is also possible that they represent a slightly higher selection as regards social status and intelligence than the kindergarten subjects. The 8 kindergarten I.Q.'s ranged from 87 to 121 (median 110), while the nursery school group I.Q.'s ranged from 87 to 158 (median 116). These I.Q.'s are all from Binet tests. I.Q.'s were avail-

able for 37 of the 39 subjects completing the test.

When giving the test, each response was scored as right, wrong, or "color blind," the last being when the number chosen was that which a color blind person would read according to the Ishihara booklet of instructions. A rough scoring system was adopted for the modified Ishihara test as follows:

2 plus credits for each correct choice
1 plus credit for each mistake *spontaneously* corrected at once by the child
2 credits deducted for each color-blind choice
1 credit deducted for each wrong choice

Adding these plus and minus credits gave a single number for each child, which was regarded as representing his level of achievement in this color test.

In scoring Plates X and XI where no choice could be considered correct since only a color-blind person is supposed to be able to see a number there, no plus credits could ever be given, but in accordance with the scoring scheme, 2 credits were deducted when the child indicated the color blind choice. Naturally, as a result of the examiner's attitude that a choice was to be made in matching Plates X and XI, practically every child indicated some card as a choice. However, their behavior while doing so was most interesting. Some said plainly at first that they could "see nothing there," or that this one was "hard to see;" then as the examiner said nothing, they would make their choices, usually indicating number 74, which was the most intricate appearing of the numbers in that series. Those who made the color-blind choice, however, (9 cases for Plate X, and 14 cases for Plate XI) usually did so promptly and without expressing any doubt by word or look, or giving any indication that this number was any harder to see than any of the others. There were 18 children who made color-blind choices for Plates X and XI. Five of these made color-blind choices for both plates; 13 for only one. However, only 1 of the 18 expressed doubt or said that the number in question (color-blind choice) was hard to see; while 17 out of the rest of the group (which did not match the color-blind numeral with Plates X and XI) said definitely that this one was "hard to see" or that they "couldn't see it," 1 saying there was "no number there," and 1 that "no one could see it."

If the total score is considered as a rough index of each child's level of achievement in this color test, it is interesting to see what relation exists in this group between total score and such factors as sex, chronological age and mental age.

There were 27 boys and 12 girls in the entire group, which of course is too small a number from which to draw conclusions as to sex differences. However, the range of scores was the same for both sexes, from minus 4 to 22 (perfect score). The median score for the boys was 16 and the median score for the girls was 14. The group of girls averaged younger, as it included only 1 kindergargten child, while there were 7 boys from the kindergarten. This fully accounts for the slightly lower median score of the girls; but there is certainly no indication that the

girls did better on the test than the boys. The results point to no sex difference.

The relation between chronological age and score and that between mental age and score is important, because if we find a closer relation between C.A. and color achievement than that between M.A. and color achievement, it may be interpreted as pointing to 2 things: (1) positively, that the increased efficiency in color vision is more a function of C.A. than it is dependent on M.A. and (2) negatively, that this particular color test is not too dependent on the child's intellectual level, but is really a measure of another capacity, viz. color vision. Computing the correlation coefficients gave the following result:

	r	PEr
Correlation C.A. with color score	.403	.086
Correlation M.A. with color score	.26	.096

$P E_{diff} = .13$ indicating 77 chances in 100 that the true difference is greater than 0. The following graph of median scores for each level of M.A. and C.A. indicates that the color test score is more dependent upon C.A. than upon M.A.

While on the subject of age as affecting achievement in this color test, the ages of 4 children who could not do the test at all are worth mentioning. These children were all cooperative in the "game," but all failed in the preliminary test of matching black and white numbers. Their age records are given in table 2. On the other hand, only one child under three years, seven months C.A. could do the test. He was three years, one month with a M.A. of three years, eleven months, which also happened to be the lowest M.A. of any in the group who succeeded. The 4 children referred to above who could not do the preliminary test may have had enough color ability to make a low score on the test, but they appeared not to have the ability to perform reliably in the multiple choice matching situation.

It was possible to retest 6 of the nursery school children after an interval of about a year. There were 3 girls and 3 boys among those retested. Table 3 gives the results.

TABLE 2

	C.A.	I.Q.	M.A.
1	2–3	121	2–9
2	2–9	?	?
3	3–1	120	3–9
4	3–4	100	3–4

TABLE 3

	1ST SCORE	2ND SCORE	GAIN IN POINTS	1ST C.A.	2ND C.A.
Boy 1	20	20	0	4–2	5–1
Girl 1	17	18	1	4	4–11
Girl 2	18	22	4	3–11	4–10
Boy 2	5	20	15	3–7	4–6
Girl 3	2	18	16	3–7	4–6
Boy 3	9	14	5	3–1	4–

A glance down the column of points gained shows a negative correlation between age and gain in points. The 3 oldest had high scores on the original test and hence there was less room for improvement. Boy 3 was the youngest child in the whole group. His gain of 5 points in the year brings him just

to the group median for his C.A. level at four years. So far as it is possible to judge from this small number of retests after a long interval, the amount of gain is less where the orignal performance was high, and the score obtained on the second text is about what would have been predicted (on the basis of the group median) for a child at that age level.

One child was given the color test 3 times within a month. He was four years, eleven months on the date of the first test and his I.Q. of 104 would have given him a M.A. of five years, two months. According to the group medians he might have been expected to make a score of 17 or 18 points. However, on the first test he made only 2 correct choices, which, with 5 wrong choices and 4 color-blind choices, would have given him the score of minus 9. There was some doubt that he had a fair chance, as the first test was given on a partly cloudy day. On a second test on a sunny day he did somewhat better, making 4 right choices, 5 wrong choices and 2 color-blind choices; which would net him a score of only minus 1. He seemed perfectly satisfied with every wrong choice, and used color names freely in talking about the cards, though the color names used were wrong more often than right. On a third test made about three weeks later, he showed some further improvement, making 6 right, 3 wrong and 1 color-blind choices, or a total score of 7. It is interesting to note that the 4 errors on this third test were on cards on which he also made mistakes on the first and second tests. In respect to these 4 mistakes, at least the test proved consistent with repetition. These cards, viz. Plates V, VI, VIII and XII, if the Ishihara interpretation is followed, do not give any clear picture of the type of color weakness which this subject might be supposed to have had. For instance, Plate V is supposed to be read as 21 by the color blind, but only on the first test did this boy choose 21, while on the other two tests he merely made wrong or irrelevant choices. Plate XII he matched once as the "red-blind" are supposed to; and the other 2 times as the "green-blind" are expected to do. Finally, in the case of Plates X and XI, in which the normal see nothing while the color blind are expected to discern a number, this boy did not make a single color-blind choice in any of the 3 tests.

The discussion of this case raises the question whether there is any reliance at all to be placed in the Ishihara test as a means of getting at "types" of color weakness, at least with children. Is it necessary to assume that the mistakes which children make in color matching would necessarily duplicate or even resemble the mistakes which a color blind adult would make on the same test? It may be more reasonable to suppose that the errors made by children who will soon have full color discrimination will be both different from and less consistent than the errors made by a true color-defective.

At any rate, it is a fact that as far as this group of children is concerned, there was not one whose errors gave a consistent picture of any type of color blindness as classified by Ishihara. In other words, not one child made all the

errors which would make it possible to classify him as "red-blind" or "green-blind." Furthermore, no two children made the same combination of wrong choices, if we exclude those making only one error on the whole test. Apparently children of incompletely developed color sense make mistakes which are less schematic and less easily divided into types than might be hoped by proponents of the various schools of color theory. Hayes (1) may be cited as one authority who believes it possible that all types of color defect may have to give way to color charts of every individual's ability:

> "The wide diversity of opinion upon the question of the classification of color defectives may be partly explained on the basis of rival color theories; but a second factor of great importance is the enormous individual differences in the subjects studied, making it seem almost equally reasonable to class some subjects in either of two groups . . . . . One wonders if we shall presently have to give up all classification by types, arrange color defectives in distribution tables and give a color graph or profile for each subject showing his efficiency or deficiency for each color in terms of a percentage of the normal or average attaiment."

From another point of view, the number of errors made by these children with each card of the Ishihara test show which cards were hardest and which easiest for them to match. The number of errors made with each Ishihara plate is as follows:

	Errors
Plate II	3
Plate III	3
Plate IV	16
Plate V	17
Plate VI	10
Plate VII	9
Plate VIII	10
Plate IX	5
Plate X	9
Plate XI	14
Plate XII	9
Plate XIII	7

The largest numbers of errors occurred with Plates V, IV and XI respectively. The fewest errors occurred with Plates II, III, and IX.

Finally, the fact that each response was timed by a stop-watch, both in the preliminary test with all black numbers and in the test proper with colored numbers, gives us a measure of what effect the introduction of color had on the length of time the children required to match each number. It was found that the central tendency was for the group to take nearly two or more times as long to match a colored number as to match the same number when it was black on a white

TABLE 4

	No. 2	No. 5	No. 6	No. 7	No. 8	No. 12	No. 26	No. 42	No. 74
Median Black...	3.3	3.6	3.9	3.0	2.6	3.5	3.7	3.5	2.8
Median Color...	6.7	9.2 7.8	5.5 5.3	5.6	4.4	8.2	7.6	6.0	9.2
Med. Dev. Black...	1.8	1.5	1.0	1.1	0.9	1.1	1.6	1.1	1.0
Med. Dev. Color...	3.5	4.4 3.9	2.3 2.3	3.0	2.0	3.7	4.1	2.9	4.8

Where two medians and median deviations are given for one number, it indicates that that digit appears twice on the Ishihara plates.

background. The median times in seconds for the uncolored and colored numbers are given in table 4.

With all the digits the children tend to take longer to match colored numbers than black numbers. Furthermore, as the median deviations show, the variability in time was much greater in the case of the colored cards than with the black and white cards.

SUMMARY

1. An adaptation of the Ishihara Test for color blindness proved applicable to a group of children between the ages of three and one-half and six years.

2. The adaptation consisted of a matching test in multiple choice form, the child being required to pick from a series of 4 cards in each group, the numbers matching those on the Ishihara plates. A similar preliminary test with black instead of colored numbers was given to show the child's ability to deal with matching numbers in a multiple choice form of test.

3. The results with this group of children showed

a. No sex difference in color discrimination.

b. A closer relation between C.A. and total score on the color test, than that between M.A. and test score.

c. Only one child under three years, six months C.A. and no child under three years, eleven months M.A. could do the test.

d. A few retests after one year gave scores approximately as high as would have been predicted for the age level of the child on the second test.

e. Three retests of one child within a month showed a slight practice effect, but a strong tendency to make the same errors in all 3 tests.

f. No child's record corresponded to the types of "color blindness" as defined by Ishihara.

g. No two children made the same combination of errors, excluding those who made only one wrong choice in the test.

h. The largest number of errors occurred with Ishihara Plates V, IV and XI respectively.

i. The fewest errors occurred with Plates II, III and IX.

j. The group took about twice as long to match each colored number as to match the same number in black. The median deviations were about twice as great for matching the colored cards as for matching the black and white cards.

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A Comparative Study of Finger Tapping in Children and Adults[1]

MILES A. TINKER AND FLORENCE L. GOODENOUGH

IN A previous investigation,[2] in which the arms of the subjects were unrestrained, the authors discovered a marked tendency for maturity of performance in tapping to be positively related to the size of muscle-group involved. When pencil, stylus, and three forms of finger tapping were compared an order of functional development from large to small muscle-groups was clearly manifested. The purpose of the present experiment is to discover whether these differences in functional development are more clearly discernible in finger tapping when the hand and arm movements are controlled.

The method employed was finger tapping on the Comptometer with the hand and wrist restrained. A hand-rest, about four inches wider than the key board of the Comptometer was constructed. The rest was covered with black velvet cloth and had two canvas straps for fastening the hand or hands to the rest. The hands were secured, palm downward, with the fingers projecting freely over the first row of the Comptometer keyboard. Adjustments for height and nearness to the keys were possible. This arrangement gave free play to finger movements, restrained all hand movements and reduced arm movements to a minimum. This arrangement necessitated practically independent finger movements when tapping with a single finger.

The index, middle and little fingers of each hand were employed separately for unimanual tapping. For the bimanual tapping the same fingers were used, like fingers of both hands operating simultaneously. Thirty kindergarten children ranging in age from four years, ten months to five years, eleven months, and 30 University students served as subjects. The sexes were approximately equally divided in each group (16 males and 14 females).

The time limit for each trial was 10 seconds in each kind of tapping and was the same for both children and adults. For determining reliability, by the test-retest method, there was a second trial on a different day for each subject. Usually the two trials occurred on successive days, and in no case was the interval between tests more than

[1] From the Psychological Laboratory and the Institute of Child Welfare, University of Minnesota.

[2] A report of a comparative study of several methods of measuring speed of tapping in children and adults, by the authors is to appear in the Journal of Genetic Psychology.

seven days. One complete series for each subject was completed at a single sitting.

In testing both the kindergarten children and the adults the procedure was first demonstrated by the experimenter, after which a brief preliminary trial was given to familiarize the subjects with the task. Directions to the children were practically the same as cited in the writers' preceding paper on tapping with the exception that the subjects were informed that their hands would be fastened to prevent the hand and arm from moving, but that this restraint would not hamper movements of the fingers. The order of unimanual testing was: index finger of right hand, index finger of left hand, middle right, middle left, little right, and little left. A brief rest period was allowed between successive trials. When the unimanual testing was completed the bimanual series was executed in the same order.

Coefficients of reliability for the finger tapping were computed for the separate fingers in both unimanual and

TABLE 1

Reliability coefficients of finger tapping on the comptometer by children and adults

KIND OF TAPPING	SINGLE TRIAL		TWO TRIALS (S-B FORMULA)	
	Children	Adults	Children	Adults
Unimanual tapping:				
Right index finger	+.73	+.74	+.84	+.85
Right middle finger	+.39	+.37	+.56	+.54
Right little finger	+.78	+.42	+.88	+.59
Left index finger	+.42	+.22	+.59	+.36
Left middle finger	+.44	+.51	+.61	+.68
Left little finger	+.41	+.63	+.58	+.77
Total right hand	+.63	+.61	+.77	+.76
Total left hand	+.50	+.54	+.67	+.70
Total unimanual	+.65	+.60	+.79	+.75
Bimanual tapping:				
Right index finger	+.55	+.78	+.71	+.88
Right middle finger	+.37	+.66	+.54	+.80
Right little finger	+.40	+.50	+.57	+.67
Left index finger	+.46	+.64	+.63	+.78
Left middle finger	+.40	+.59	+.57	+.74
Left little finger	+.47	+.47	+.64	+.64
Total right hand	+.55	+.71	+.71	+.83
Total left hand	+.74	+.53	+.85	+.69
Total bimanual	+.69	+.64	+.82	+.78
Grand total—both hands	+.76	+.76	+.86	+.86

bimanual tapping by correlating test with retest scores. In addition, the reliability coefficients of the combined scores for each hand, for each method, and for the grand total were ascertained. As the intercorrelations in this investigation were computed by the use of combined scores for the 2 trials, the Spearman-Brown formula was used to obtain the reliability of scores on trial 1 plus scores on trial 2. All correlations were calculated by the Pearson product-moment method. Table 1 gives the reliability coefficients.

For a single trial, all but 4 coefficients of reliability are higher than +.40, the range being +.22 to +.78. For the 2 trials summed the range is +.36 to +.88. In general, the reliability of tapping tends to be slightly higher for children in unimanual tapping, and somewhat higher for adults in bimanual tapping. The higher reliability of bimanual tapping with adult subjects can be explained in part by the fact that the children, in this kind of tapping, looked at and apparently devoted their attention to one hand almost entirely, or switched their fixation alternately from one hand to the other. The totals in unimanual and in bimanual tapping have slightly higher reliabilities for children, but the grand total is equally reliable for children and adults. (Single score +.76; summed scores +.86). In the case of adults, the index finger is most reliable in 3 of 4 determinations; with children there is no consistent trend but the right index finger and right little finger in unimanual tapping have comparatively high reliabilities.

In table 2 are given the means and the standard deviations of the separate trials for tapping rate of children and adults. The table also shows the ratio between the means of the children and of the adults, i.e., the proportion of the average speed of adults that has been attained by the children in each kind of tapping.

Examination of the mean scores given in the first four columns of figures reveals the following trends: (1) With children there is a marked practice effect in finger tapping. (2) Adult tapping scores show no practice effects. The second score is frequently smaller than the first. (3) With both the child and the adult group the index and middle fingers yield tapping scores which are nearly equal to each other in magnitude. In some cases the middle finger taps faster, in other cases the index finger. (4) The tapping speed of the little finger is much slower than that of the other fingers, particularly in the child group. (5) Bimanual tapping is slightly slower than unimanual tapping for both groups. (6) Speed of tapping with fingers of the left hand is slower than with fingers of the right hand.

The standard deviations given in the fifth to eighth rows of table 2 show that, in the unimanual tapping of children, performance of the middle finger is least variable. Also the variabilities of tapping scores for the little finger are relatively very high, especially in the case of children.

The last two columns of table 2 reveal an interesting developmental trend in the comparative maturity of the various muscle groups involved in the tapping movements. As seen in the first row, in tapping with index

finger, the children have attained 41 per cent of adult efficiency on the first trial and 46 per cent on the second. These last two columns of the table show the following trends: (1) In every instance but one the order of comparative maturity of performance is middle finger first, index finger next and little finger last. (2) The index and middle fingers maintain about the same levels of comparative efficiency throughout the series. (3) There is a greater group difference in maturity of tapping in case of the little finger than with the other two fingers. (4) On the second trial the children are always closer to the adult level than on the first. (5) The comparative

TABLE 2

Means and standard deviations of number of taps in ten seconds by children and adults for finger tapping on the comptometer

KIND OF TAPPING	MEAN SCORE				STANDARD DEVIATION				MEAN SCORE	
	Children		Adults		Children		Adults		Ratio: child to adult	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
Unimanual tapping:										
Right index finger	22.9	24.9	55.5	54.3	5.1	5.5	6.9	6.5	.41	.46
Right middle finger	23.6	25.1	54.5	52.9	3.3	3.8	5.9	3.7	.43	.47
Right little finger	9.9	12.2	44.6	42.3	6.5	8.6	6.5	7.0	.22	.29
Left index finger	22.2	23.5	50.3	49.9	4.5	3.9	6.3	3.7	.44	.47
Left middle finger	22.0	24.3	49.3	49.8	3.7	3.6	4.5	5.6	.45	.49
Left little finger	7.8	10.9	40.8	40.5	5.8	5.9	5.4	5.6	.19	.27
Total right hand*	55.2	61.3	153.7	149.6	10.2	12.8	12.6	11.5	.36	.41
Total left hand	50.7	57.0	140.0	138.8	9.8	9.8	13.7	11.9	.36	.41
Total both hands	105.5	117.8	293.3	287.8	18.4	20.7	23.1	19.8	.36	.41
Bimanual tapping:										
Right index finger	22.0	25.6	52.5	50.3	5.8	4.5	6.7	6.7	.42	.51
Right middle finger	22.7	23.9	52.7	49.5	4.8	4.9	6.3	7.8	.43	.48
Right little finger	6.5	9.5	42.8	39.1	5.8	5.6	6.8	7.6	.15	.24
Left index finger	20.5	23.9	50.1	49.3	6.5	4.5	6.2	6.7	.41	.48
Left middle finger	20.8	22.8	47.8	46.3	6.1	4.9	7.1	7.9	.42	.49
Left little finger	5.4	8.1	37.5	36.6	4.5	5.5	8.9	6.9	.14	.22
Total right hand	49.9	57.6	147.9	137.1	13.1	10.7	14.4	16.8	.34	.42
Total left hand	46.0	53.3	134.5	131.5	13.8	11.7	15.6	16.4	.34	.41
Total both hands	96.4	111.3	281.6	269.9	24.8	21.3	27.0	30.7	.34	.41
Grand total—both hands	201.3	228.0	577.0	556.3	37.4	39.9	41.4	46.5	.35	.41

* All averages and standard deviations are computed from original scores.

maturity of performance for the total of right hand, of left hand, and of both hands is the same (36 per cent in unimanual and 34 per cent in bimanual tapping. (6) Finger tapping of children approaches nearest adult proficiency when the middle finger is used (49 per cent on the second trial).

In our previous study of finger tapping with the arm unrestrained, the developmental trend in comparative functional maturity revealed the children to be nearest adult proficiency with the index finger. The middle and little finger than followed in order. Both the first study and the present investigation reveal about the same trends in scores for the different fingers, i.e., scores for index and middle fingers are about equal in each kind of tapping, but in only 5 of 16 instances are the scores for the index fingers higher than those for the middle fingers. The developmental tendency in comparative functional maturity revealed in the present experiment (middle finger nearest adult maturity, then index finger and then little finger) is probably approximately correct since arm movements have been controlled in this study. One should emphasize the fact, however, that the difference in functional maturity between the middle finger and index finger is slight.

Table 3 shows the intercorrelations of the scores in finger taping for each of the 2 groups of subjects. In computing these correlations the sums of the scores for the 2 trials were employed. In the last column of the table are given the correlations between the correlation coefficients for the children and those for adults when each finger under a certain condition is correlated with every other finger under each of the various conditions. Thus when the series of coefficients for children in row one of the table are correlated with the series for adults in row two, a correlation of +.82 is obtained. These coefficients in the last column reveal the extent to which a constant tendency in the relationships between the tapping speeds of the different fingers persists from childhood to maturity. The range of these coefficients is from +.17 to +.88 with an average of +.61. In our previous tapping investigation the range of comparable coefficients was +.22 to +.84 with the average at +.61. In the present study all but two correlations are +.63 or above. This indicates that, although some fingers are more closely related to each other in speed of tapping than others (see rest of table), this relationship does not change greatly with age.

A survey of the first 12 columns of table 3 reveals 11 negative coefficients out of a total of 132. The range of correlations is −.18 to +.84 Method of tapping (unimanual or bimanual) sees to have little influence on the intercorrelations for either children or adults since many of the highest as well as many of the lowest coefficients are found both when similar methods and when unlike methods are involved. Analysis of the correlation coefficients of table 3 reveals the following trends: (1) Any specific finger tends to yield performance which correlates well with performance by the same finger of the other hand, and with performance by the same finger in another method (unimanual or bimanual); (2)

Tapping scores of the index fingers yield a fair correlation with those of the middle fingers; (3) scores of the little fingers show little or no correspondence to scores of either of the other fingers. In our previous study the relationship between the more nearly adjacent fingers tended to be closer than that between fingers more widely separated.

Twenty-three of the kindergarten

TABLE 3

Intercorrelations between scores on finger tapping for children and for adults

	U-R INDEX	U-R MIDDLE	U-R LITTLE	U-L INDEX	U-L MIDDLE	U-L LITTLE	B-R INDEX	B-R MIDDLE	B-R LITTLE	B-L INDEX	B-L MIDDLE	B-L LITTLE	r BETWEEN GROUPS
U-R* Index:													
Children.....		+.50	+.26	+.71	+.44	+.45	+.73	+.54	+.33	+.47	+.48	+.25	+.82
Adults.....		+.40	+.07	+.62	+.32	+.05	+.57	+.31	−.02	+.47	+.15	−.06	
U-R Middle:													
Children.....	+.50		−.17	+.48	+.59	−.06	+.28	+.48	−.09	+.22	+.37	−.06	+.85
Adults.....	+.40		+.01	+.53	+.62	+.04	+.38	+.59	+.17	+.40	+.47	−.07	
U-R Little:													
Children	+.26	−.17		+.10	+.03	+.70	+.31	+.33	+.73	+.44	+.29	+.58	+.62
Adults.....	+.07	+.01		+.11	+.17	+.08	+.13	+.25	+.62	+.13	−.07	+.17	
U-L Index:													
Children.....	+.71	+.48	+.10		+.55	+.39	+.51	+.49	+.14	+.52	+.48	+.07	+.88
Adults.....	+.62	+.53	+.11		+.67	+.43	+.78	+.62	+.23	+.57	+.59	+.10	
U-L Middle:													
Children.....	+.44	+.59	+.03	+.55		+.12	+.19	+.52	+.01	+.28	+.65	.00	+.83
Adults.....	+.32	+.62	+.17	+.67		+.48	+.47	+.42	+.28	+.58	+.68	+.22	
U-L Little:													
Children.....	+.45	−.06	+.70	+.39	+.12		+.44	+.29	+.70	+.62	+.42	+.68	+.17
Adults.....	+.05	+.04	+.08	+.43	+.48		+.31	+.23	+.40	+.48	+.45	+.66	
B-R Index:													
Children.....	+.73	+.28	+.31	+.51	+.19	+.44		+.54	+.37	+.72	+.41	+.34	+.69
Adults.....	+.57	+.38	+.13	+.78	+.47	+.31		+.76	+.15	+.84	+.55	−.02	
B-R Middle:													
Children.....	+.54	+.48	+.33	+.49	+.52	+.29	+.54		+.37	+.53	+.72	+.28	+.64
Adults.....	+.31	+.59	+.25	+.62	+.42	+.23	+.76		+.34	+.52	+.51	−.04	
B-R Little:													
Children.....	+.33	−.09	+.73	+.14	+.01	+.70	+.37	+.37		+.34	+.39	+.68	+.66
Adults.....	−.02	+.17	+.62	+.23	+.28	+.40	+.15	+.34		+.07	+.25	+.57	
B-L Index:													
Children.....	+.47	+.22	+.44	+.52	+.28	+.62	+.72	+.53	+.34		+.59	+.34	+.54
Adults.....	+.47	+.40	+.13	+.57	+.58	+.48	+.84	+.52	+.07		+.54	−.18	
B-L Middle:													
Children.....	+.48	+.37	+.29	+.48	+.65	+.42	+.41	+.72	+.39	+.59		+.36	+.64
Adults.....	+.15	+.47	−.07	+.59	+.68	+.45	+.55	+.51	+.25	+.54		+.27	
B-L Little:													
Children.....	+.25	−.06	+.58	+.07	.00	+.68	+.34	+.28	+.68	+.34	+.36		+.63
Adults.....	−.06	−.07	+.17	+.10	+.22	+.66	−.02	−.04	+.57	−.18	+.27		

* U=unimanual; B=bimanual; R=right; L=left.

children in this experiment had also served as subjects on the earlier study in which the arms were unrestrained. An interval of three months elapsed between experiments. Intercorrelations between tapping scores made with arms restrained and with arms unrestrained are given in table 4. The coefficients indicate that there is only a small amount of correspondence present between performance under the 2 conditions. The coefficients range from +.09 to +.75 with a correlation of +.45 for the grand total.

TABLE 4

Comptometer tapping with arm unrestrained vs. comptometer tapping with arm restrained (children only)

FINGER AND HAND USED	UNIMANUAL TAPPING	BIMANUAL TAPPING
Right index	+.27	+.36
Right middle	+.31	+.47
Right little	+.25	+.25
Left index	+.75	+.09
Left middle	+.51	+.45
Left little	+.24	+.36
Total right hand	+.15	+.49
Total left hand	+.67	+.36
Total both hands	+.33	+.45

Grand total—bimanual plus unimanual, $r = +.45$

SUMMARY

1. The rate of finger tapping was measured for a group of 30 kindergarten children and for 30 college students.

2. Arm movements were restrained by securing the hand, palm downward, on a hand rest, in such a manner that the hand was immovable and the wrist and arm movements were reduced to a minimum. The fingers were entirely free from restraint.

3. A Comptometer was employed to measure the speed of tapping. The index, middle, and little fingers of each hand were tested independently (unimanual tapping) and simultaneously (bimanual tapping).

4. Reliabilities were computed by correlating test with retest scores. For the single fingers there was a tendency for the tapping scores to be more reliable for children in unimanual and for adults in bimanual. The totals for both unimanual and bimanual tapping are slightly more reliable for children than adults, but the grand total is equally reliable for both children and adults. (Single score, +.76; summed scores +.86).

5. In both the child and the adult group the index and middle fingers yield tapping scores approximately equal in magnitude. Tapping of the middle finger was only a little faster than that of the index finger. The little finger taps at a much slower rate than the other fingers. Right hand tapping is slower than left, and bimanual tapping is slower than unimanual.

6. When the children are compared with the adult group the order of comparative maturity of performance is middle finger nearest adult maturity, index finger next and little finger last. The comparative maturity of performance for the total of right hand, total of left hand, and of both hands together is the same (34 per cent).

7. Although some fingers are more closely related to each other in speed of tapping than others, this relation-

ship does not change greatly with age. (Average correlation between coefficients for children and adults is +.61).

8. Tapping by any finger tends to correlate well with tapping by the same finger of the other hand or tapping by the same finger in another method (unimanual and bimanual).

9. Tapping scores of the index and middle finger tend to correlate more highly with each other than the scores of either of these fingers with the scores of the little finger.

10. There is a small degree of correspondence between scores for finger tapping with arm and hand restrained and scores with arm and hand unrestrained in the case of the children.